HEALTH ASPECTS OF BIOSOLIDS LAND APPLICATION

Prepared for

City of Ottawa

March 2002

Prepared under the direction of the Medical Officer of Health by:

Erik Apedaile, P.Ag.

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1 April, 2002

Dr. Robert Cushman
Medical Officer of Health
City of Ottawa
495 Richmond Road
Ottawa, ON

Subject: Health Aspects of Biosolids Land Application

Dear Dr. Cushman:

Based on the information collected in the report "Health Aspects of Biosolids Land Application" (March 2002), as a qualified community medicine specialist and independent reviewer, I support your recommendation to continue with the practice of biosolids land application.

I am making this recommendation in the context of the implementation of the Best Management Practices by the City of Ottawa.

Yours truly,

Dr. Donald Cole, M.D., M.Sc., FRCPC
Associate Professor

Executive Summary

Built in 1961, the Robert O. Pickard Environmental Centre (ROPEC) is one of the largest wastewater treatment facilities in Canada. The facility treats an average capacity of 545 million litres of wastewater per day, with a peak capacity of 1,362 ml/d. It produces about 30 dry tonnes of dewatered biosolids (approximately 4 truck loads) per day.

In August 2000, the City initiated its five-year update of the Biosolid Management Plan. The update included a comprehensive review of current practices, identification and assessment of alternatives, and extensive public consultation. The update was based on the premise that the Province of Ontario is responsible for regulating biosolids for protecting public health.

In December 2001, while accepting the recommendations of the Biosolids Management Plan Update, Ottawa City Council directed the Medical Officer of Health (MOH) to review the safety of land-applying biosolids and to develop application standards that meet or exceed the current provincial standards. Specifically, the MOH was directed to take the following actions:

- Retain the necessary experts to conduct a scientific review of the safety of spreading biosolids
- Recommend interim best management practices for the City's biosolids management program
- Present the expert analysis and the new standards to the Environmental Services Committee

The biosolids land application program for Ottawa was suspended pending the outcome of the MOH's recommendation.

Scope

In response to Council's directive, the MOH retained Apedaile Environmental and CH2M HILL Canada Limited to undertake the following:

Task 1: Search, collect, and summarize the current literature on health aspects of land-applying anaerobically digested, dewatered biosolids

Task 2: Interview specialists to provide scientific and regulatory perspectives on current work in the biosolids area

Task 3: Develop interim best-management practices based on current practices, research, and experience

The Medical Officer of Health elected to undertake a 4th Task:

Task 4: The City was to retain a qualified third-party health specialist for evaluating the information and providing feed back to the MOH

The project team recognizes that the issue of human health related to land application of biosolids is of general public concern and, while there is a great deal of literature related to this topic, there also is much disagreement.

Every attempt has been made to reflect views from across the spectrum on this issue. The intent of this report was to identify the research and information available for the sole use of the Medical Officer of Health in his determination regarding the safety of land application of biosolids for the City of Ottawa. The opinions and views expressed in the literature and in interviews are those of the authors and interviewees and not of the City or its consultants.

Methodology

The project focused on collecting health-related information bearing on the type of biosolids generated at the Pickard Centre and on its land-application practices. The project team collected scientific literature and abstracts, and spoke with a series of key contacts and specialists in the field of biosolids management related to human health issues.

During the review two key difficulties emerged:

1. There is a lack of multi-disciplinary research and biosolids-specific medical data
2. The vast body of research related to biosolids and land application required a narrowed field of focus given the time constraints of this project

To narrow its focus, the team used a recently published review of literature and stakeholder groups as a starting point for collecting scientific literature. This review, *Fate and Significance of Selected Contaminants in Sewage Biosolids Applied to Agricultural Land Through Literature Review and Consultation with Stakeholder Groups* (April 2001) was commissioned by the Water Environment Association of Ontario (WEAO). The WEAO review examined a broad range of contaminants and divided them into two groups:

Group I contaminants: These have sufficient, credible scientific evidence to demonstrate that they are not a concern in sewage biosolids

Group II contaminants: These do not have sufficient, credible scientific evidence to demonstrate they are not a concern in sewage biosolids

Therefore, the team focused on the Group II contaminants, namely:

- Pathogens
- Unregulated metals
- Estrogenic hormones and pharmaceutically active compounds

The team also explored emerging issues (PBDEs and health effects related to odours) and health studies. An overview of the literature in these areas is presented in this review, however, as the WEAO studied noted, all of these areas are in need of further research. The review team developed a database of the literature considered in preparing this report , and collected and collated hard copies of the majority of the literature.

Key contacts and specialists were selected to represent the breadth of scientific and regulatory opinion on health aspects of biosolids land application. People involved in developing and implementing regulations in the United States and Canada, as well as people from research institutions who have been critical of the regulations were selected for interviews. In addition, published researchers were contacted for context and clarification of their published work. The ability to interview key contacts and specialists was limited by time and budget.

The literature and interviews with key contacts and specialists assisted in the development of a series of interim best management practices (BMPs). One premise used to develop the interim BMPs was that limiting public contact with biosolids may mitigate potential public health risks from exposure. In addition, the BMPs sought to respond to community concerns specific to the City of Ottawa identified during the Biosolids Management Plan Update public consultation process. The interim BMPs cover all aspects of the land application program from selecting application sites, the approval process, and spreading activities, to record keeping and auditing. Emergency measures and at-source controls also are addressed.

Finally, in accordance with Task 4, a qualified and independent third party, Dr. Donald Cole, MD, an expert in community medicine with the University of Toronto, was retained directly by the Medical Officer of Health. Dr. Cole assessed the information collected in Tasks 1-3 and provided feedback to the MOH in his determination regarding the safety of biosolids land application.

Contents

Appendixes

Acronyms and Abbreviations

Ag	silver
Al	aluminum
ATPase	adenosinetriphosphatase
B	boron
Ba	barium
Be	beryllium
BMP	best management practice
CCME	Canadian Council of Ministers of the Environment
CWA	Chemical Waste Act
F-	fluoride
JAMA	Journal of the American Medical Association
LPS	lipopolysacharides
MOE	Ministry of Environment (Ontario)
MOH	Medical Officer of Health
MSW	municipal solid waste
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
PBDEs	polybrominated diphenyl ethers
PCB	polychlorinated biphenyl
PPCP	pharmaceuticals and personal care products
ROPEC	Robert O. Pickard Environmental Centre
Sb	antimony
Sn	tin
Sr	strontium
STP	sewage treatment plant
Ti	titanium
Tl	thallium
TS	total solids
USEPA	US Environmental Protection Agency
V	vanadium
VBNC	viable but nonculturable
WEAO	Water Environment Association of Ontario

1. Background and Methodology

1.1 Rationale for the Review

Built in 1961, the Robert O. Pickard Environmental Centre is one of the largest wastewater treatment facilities in Canada. Located on a 60-hectare (150 acre) site along the Ottawa River, the facility treats domestic, commercial, and industrial wastewater before returning the treated water to the Ottawa River. The City, which owns the centre, has a population of some 785,000.

The facility treats an average capacity of 545 million litres of wastewater per day, with a peak capacity of 1,362 ml/d. It produces about 30 dry tonnes of dewatered biosolids (approximately 4 truck loads) per day. Primary sludge and secondary waste-activated sludge are combined and anaerobically digested under mesophyllic temperatures for approximately 20 days prior to dewatering to a 30-percent dry solids cake. The City of Ottawa's biosolids management program undergoes a review and update approximately once every five years.

In August 2000, the City of Ottawa initiated its most recent update to its Biosolids Management Plan to create a long-term biosolids management strategy through to 2021. The update included a comprehensive review of current practices, identification and assessment of biosolids management alternatives, a review of the regulatory framework for biosolids and extensive public consultation. This update was based on the premise that the Province of Ontario is responsible for regulating biosolids for protecting public health.

The recommendations of the Biosolids Management Plan Update were submitted to the Environmental Services Committee of the Ottawa City Council in November of 2001 and to the Ottawa City Council itself in December of 2001. While the recommendations of the Biosolids Management Plan Update were accepted, Council also directed the Medical Officer of Health (MOH) to review the safety of land-applying biosolids and to develop application standards that meet or exceed the current Provincial standards. Specifically, the MOH was directed to take the following actions:

- Retain the necessary experts to conduct a scientific review of the safety of spreading biosolids
- Recommend interim best management practices for the City's biosolids management program
- Present the expert analysis and the new standards to the Environmental Services Committee in spring 2002

The biosolids land application program for Ottawa was suspended pending the outcome of the MOH's recommendation.

1.2 Scope

The project was organized into four tasks:

Task 1: Search, collect, and summarize the current literature on health aspects of land-applying anaerobically digested, dewatered biosolids

Task 2: Interview specialists to provide scientific and regulatory perspectives on current work and emerging issues in the biosolids area and who represent a range of opinion on land application of biosolids

Task 3: Develop interim best-management practices based on current practices, research, and experience

A fourth task was undertaken independently by the City:

Task 4: Retain a qualified third-party health specialist for evaluating the information and providing feed back to the MOH

The project team recognizes that the issue of human health related to land application of biosolids is of general public concern and, while there is a great deal of literature related to this topic, there also is much disagreement.

Every attempt has been made to reflect views from across the spectrum on this issue. The intent of this project was to identify the research and information available for the sole use of the Medical Officer of Health in his determination regarding the safety of land application of biosolids for the City of Ottawa. The opinions and views expressed in the literature and in interviews are those of the authors and interviewees and not of the City or its consultants.

1.3 Methodology

The project focused on collecting health-related information bearing on the type of biosolids generated at the Pickard Centre and on its land-application practices. The project team collected scientific literature and abstracts, and spoke with a series of key contacts and specialists in the field of biosolids management related to human health issues.

One of the key difficulties in summarizing the literature for the Medical Officer of Health was the lack of multi-disciplinary research. Work that provides detailed medical data lacks information on the type of biosolids, the application rate, and field practices. Treatment technologies and field practices vary dramatically from one jurisdiction to another. There is a strong need for the combined expertise of agronomists, engineers, and health professionals to be brought to bear on the primary research in this field.

A second difficulty was the vast body of research related to biosolids and land application and the time constraints for the project. Specifically, three months were available to complete the assignment before the Medical Officer of Health was to report to the committee. To narrow its focus, the team used a recently published study of literature and stakeholder groups as a starting point for collecting scientific literature. This review, *Fate and Significance of Selected Contaminants in Sewage Biosolids Applied to Agricultural Land*

Through Literature Review and Consultation with Stakeholder Groups (April 2001) was commissioned by the Water Environment Association of Ontario (WEAO). The WEAO review examined a broad range of contaminants and divided them into two groups:

Group I: Contaminants that have sufficient, credible, scientific information to assure the public that the current agricultural land application program/guidelines are adequate to protect the well being of soils, crops, animals, human health, groundwater quality, and surface water quality.

Group II: Contaminants that do not have sufficient, credible, scientific information to assure the public that the current agricultural land application program/guidelines are adequate to protect the well being of soils, crops, animals, human health, ground, and surface water qualities.

With the Ottawa City Council's mandate to "review … the safety of spreading of biosolids," the review team focused on Group II contaminants. The executive summary of the WEAO report is provided in Appendix B, and the entire document is provided as supplementary resource material.

The Group II contaminants identified in the WEAO study are:

- Pathogens
- Unregulated metals
- Estrogenic hormones and pharmaceutically active compounds

These areas were the focus of this project, together with a fourth category, emerging issues, to take into account information that arose during the 12 months between the time the bulk of the WEAO work was completed and the current review was initiated. An additional element, health studies, was added to the research areas because of the focus on public health.

The literature and interviews with key contacts and specialists were used to assist with the development of a series of interim best management practices. The premise behind the interim BMPs is that limiting public contact with biosolids may mitigate potential public health risks from exposure. The BMPs also responded to some specific public concerns raised during public consultation for the Biosolids Management Plan Update. The interim BMPs cover all aspects of the land application program, from selecting application sites, the approval process, and spreading activities, to recordkeeping and auditing. Emergency measures and at-source controls also are addressed.

In accordance with Task 4, a qualified and independent third party, Dr. Donald Cole, M.D., an expert in community medicine with the University of Toronto, was retained directly by the City. Dr. Cole assessed the information collected and provided feedback to support the MOH in his determination regarding the safety of biosolids land application. On the basis of the information in this report, supporting documents, and Dr. Cole's review the MOH will prepare a separate report for Environmental Services Committee containing his recommendations for the biosolids land application program.

1.3.1 Task 1: Compile Literature

To meet the requirements of the first task, the project team compiled a list of published articles identified through databases included in the literature search, listed below. No information was found from the Journal of the American Medical Association (JAMA), Lancet, or the New England Journal of Medicine.

Agricola – has been maintained since 1970 to provide selective worldwide coverage of primary information sources in agriculture and related fields such as ecology, food regulations and science, forestry, health, nutrition and veterinary science.

American Medical Association Journals – has been maintained since 1982, and includes articles from 11 medical journals, including JAMA, and addresses all subject areas relating to the practice of medicine, including health, medical engineering, nutrition, pharmaceuticals, safety, and toxicology.

Biosis Previews – has been maintained since 1969 and provides worldwide coverage of research in the biological and biomedical sciences, including agriculture, alternative medicine, biochemistry, biotechnology, ecology, environment, food science, forestry, health, marine, medicine, nutrition, pharmaceuticals, pollution, safety, toxicology, waste, and water. Some sources include academic research, government reports, reviews and US patents.

Current Contents Search – has been maintained since 1995 and contains the full content page of every leading journal and book. Subject areas include clinical medicine; life science; engineering, technology, and applied sciences; agriculture, biology, and environmental sciences; physical, chemical, and earth sciences; social and behavioural sciences; and arts and humanities.

EI Compendex – has been maintained since 1970 and provides abstracted engineering and technological literature. Subjects covered include civil, energy, environmental, geological, and biological engineering; electrical, electronics, and control engineering; chemical, mining, metals, and fuel engineering; mechanical, automotive, nuclear, and aerospace engineering; computers, robotics, and industrial robots.

Embase – has been maintained since 1974 and provides an index of worldwide literature on human medicine and related disciplines including drug literature. Other subject areas include alternative medicine, biological chemistry, science and technology, health and nutrition, pharmaceuticals, safety, toxicology, and health.

Enviroline – has been maintained since 1971 and covers worldwide environment-related information providing indexing and abstracting. Subject areas include management, technology, planning, law, political science, economics, geology, biology, and chemistry as they relate to environmental issues.

The Lancet – has been maintained since 1986 and contains full text articles from the weekly general medical journal, *The Lancet*. The articles include all subject areas relating to human health.

Medline – has been maintained since 1966 and is a major source of biomedical literature, including communication disorders, population, and reproductive biology.

New England Journal of Medicine – has been maintained since 1984 and contains full text articles from the *New England Journal of Medicine*. Subject areas include health and nutrition, pharmaceuticals, safety, and toxicology.

Pollution Abstracts – has been maintained since 1970 and includes references to environment-related literature on pollution, its sources, and its control. Subjects include air pollution, environmental quality, noise pollution, pesticides, radiation, solid wastes, and water pollution.

SciSearch – has been maintained since 1974 and includes a multidisciplinary index to the literature of science, technology, biomedicine, and related disciplines. Subject areas range from astronomy to manufacturing to all disciplines and branches of the biological, chemical, geological, and physical sciences.

The Water Environment Research Federation (www.werf.org) and the US Environmental Protection Agency (USEPA) Office of Water (www.epa.gov/owm) web sites also were searched for literature.

The focus on public health was used as a screening criterion for the large body of literature on the subject of biosolids. By applying this criterion, for example, the issue of nutrient movement into surface waters, as well as research related to soil-plant relations and yield trials would not be within the scope of this review.

The terms 'biosolids', 'sewage sludge', and 'sewage biosolids' are used interchagably, depending upon the useage by the author being quoted. In most cases, these terms are used to refer to anaerobically digested solids resulting from the treatment of municipal sewage.

In some cases, references cited in the literature identified through the database searches were collected where the information pertained to health aspects of biosolids land application. Articles and references also were provided by the key contacts and specialists who were interviewed, as well as by colleagues, Ottawa City staff, internal reviewers, and Dr. Cole.

In total, 168 abstracts and papers were collected from this search. A Microsoft Access database was created to allow the articles to be searched by title, author, date, or key word. Each article has a unique identification number and includes the fields for the author, date, title, publisher, key words, abstract, and category. In addition to the electronic database, a full copy of each article, where available, has been provided as part of this undertaking. The copies were catalogued in alphabetical order and filed in three-inch binders for easy access.

1.3.2 Task 2: Current Context and Emerging Issues (Interviews)

Key contacts and specialists were selected to represent the breadth of scientific and regulatory opinion on health aspects of biosolids land application. The selection of interviewees did not attempt to be exhaustive, but rather was designed to assist the MOH and the third-party public health specialist in understanding the current context of the debate surrounding biosolids, and to probe the current directions of research in this area.

Key people involved in developing and implementing regulations in the United States and Canada, as well as people from research institutions who have been critical of the regulations were contacted for interviews. In addition, some published researchers were contacted for context and clarification of their published work. The ability to interview key contacts and specialists was limited by time and budget.

Ten individuals were interviewed on four key topics:

1. Current research into health-related aspects of biosolids land application
2. Significant findings of the interviewee's work
3. Implications of his/her research for municipalities spreading biosolids
4. Identification of landmark papers and research in his/her field of study

The interviewee, their affiliations, and their focus of expertise are provided in Table 1-1 in alphabetical order. The interviews have been documented and are presented in Appendix A. The opinions and views expressed in the interviews are those of the interviewees and not of the City or its consultants. The City and its consultants take no responsibility for the accuracy or correctness of the information.

TABLE 1-1
Current-Context Interviews

Interviewee	Affiliation	Expertise
Rufus Chaney	US Department of Agriculture, Environmental Chemistry Lab	Led the USEPA Regulation 503 team on polychlorinated biphenyl (PCB) pathway calculations and limits. Also has expertise in metals in land application.
Michael Goss	Chair of Land Stewardship, University of Guelph	Prepared commissioned paper for Walkerton Inquiry on well contamination. Specialist in biosolids and manure land application.
Robert Hale	Department of Environmental Health Science, Virginia Institute of Marine Science, College of William and Mary	Researcher on accumulation of brominated diphenyl ethers (flame retardants) in fish and biosolids in North America
Ellen Harrison	Director of the Cornell Waste Management Institute	Co-author of the "Case for Caution," which highlighted concerns associated with the basis for the USEPA 503 Regulation
Tony Ho	Senior Specialist on Wastewater, Drinking Water, Wastewater and Watershed Standards, Standards Development Branch, Ontario Ministry of Environment	Member of the Ontario Biosolids Utilization Committee, sponsor for the Ontario Unregulated Metals Study, sponsor for the Ontario Biosolids Environmental Management System Pilot
David Lewis	University of Georgia / USEPA National Exposure Research Laboratory	USEPA "whistleblower" on health effects of land application. Key witness in the Synagro lawsuit.
Murray McBride	Cornell University, Professor of Soil Science	Co-author of the "Case for Caution," which highlighted concerns associated with the basis for the USEPA 503 Regulation; Researcher on metals
Raymond Singer	Neurotox Consultants, New Mexico	Conducted an evaluation on neuro-psychological effects of biosolids land application on a farm family in Washington state.

TABLE 1-1
Current-Context Interviews

Interviewee	Affiliation	Expertise
Susan Springthorpe	Associate Director of the Centre for Research on Environmental Microbiology, Faculty of Medicine, University of Ottawa	Environmental microbiology. Conducted studies on pathogens in Ottawa's biosolids and on their movement through soil.
Edward Topp	Agriculture and Agrifood Canada	Lead researcher on the fate of endocrine disrupters (nonyl phenols, estrogenic hormones) in biosolids and manure land application

In addition, the project team attempted to contact a number of other notable researchers, but was unable to conduct interviews, either because they could not be reached in the time available or because they declined to be interviewed (Table 1-2).

TABLE 1-2
Candidates for Current Context Interviews Who Were Not Interviewed

Interviewee	Affiliation	Expertise	Reason Interview Was Not Conducted
Charles Gerba	University of Arizona, Department of Soil, Water and Environmental Science.	Co-author on high profile papers on aerosol pathogens	Unable to contact, did not return calls
Jennifer Hargraves	University of Guelph, Department of Land Resource Science	Coordinating the Ontario unregulated metals study sponsored by the MOE	Declined to be interviewed as research is ongoing
Jack Trevors	University of Guelph, Department of Microbiology	Professor of Microbiology, expertise in soil microbiology	Did not have any comment on health aspects
Mike Van den Bosch	Manitoba Conservation	Involved in developing metals limits for the Canadian Council of Ministers of the Environment	Unable to establish an interview time during the review
Paul Voroney	University of Guelph, Department of Land Resource Science	Professor of Soil Science, expertise in soil biology	Did not have any comment on health aspects
Mel Webber	Environmental Consultant	Lead researcher for the WEAO Study	Indicated that he did not have anything to add to the WEAO report

1.3.3 Task 3: Interim Best Management Practices

Before the biosolids land-application program was suspended, the biosolids land application practices of the City of Ottawa went beyond the requirements of the Provincial

Guidelines in a number of areas. In general, these practices were followed, although no systematic program of "best management practices" had been defined.

Nevertheless, throughout the public consultation regarding the Biosolids Management Plan Update (August 2001) for the City of Ottawa, a recurring theme was a lack of confidence in the existing biosolids land application guidelines. Specific concerns included enforcement of the guidelines and site certificates of approval. The Province of Ontario has three initiatives underway that eventually should address best management practices for biosolids:

1. Review of the *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land.*
2. Development and implementation of the Nutrient Management Act and related regulations
3. Development and demonstration of an environmental management system for biosolids management; the City of Ottawa is one of three pilot cities for this project, which is receiving some funding from the MOE and Environment Canada

It is not expected that these initiatives will be realized in time for the 2002 land application season. In the interim, the Ottawa City Council has expressed a desire that the City have best management practices in place if the Medical Officer of Health indicates that the program can proceed.

In the context of this review, best management practices relate to both what happens on the field as well as to management practices for the program. They were developed based on the results of the research and current context interviews, and in response to community concerns specific to the City of Ottawa.

1.3.4 Task 4: Third-Party Public Health Specialist Review

A qualified third party, independent of Apedaile Environmental and CH2M HILL, was identified and retained by the City to assess the information collected, and to provide feedback to the Medical Officer of Health to help him in his determination regarding the safety of biosolids land application. The third party had to meet the following requirements:

- Be qualified in community medicine
- Not have been involved previously with health aspects of biosolids land application
- Have experience in epidemiology or risk assessment

Several individuals, including medical officers of health in other jurisdictions, identified Dr. Donald Cole, MD, for this role. He is associate professor with the Department of Public Health Sciences, Faculty of Medicine, University of Toronto. Dr. Cole holds a medical degree from the University of Toronto, and did post-graduate work in epidemiology of tropical and parasitic disease. He went on to obtain a diploma in occupational health and safety and received his Master of Science in design, measurement, and evaluation of health services. Dr. Cole's curriculum vita is provided in Appendix D.

It is expected that Dr. Cole will assist the Medical Officer of Health in preparing his recommendations for the Environmental Services Committee and the Ottawa City Council.

1.3.5 Biosolids Link to Human Health

A key factor needed in linking human health to contaminants and pathogens in biosolids is a route of exposure.

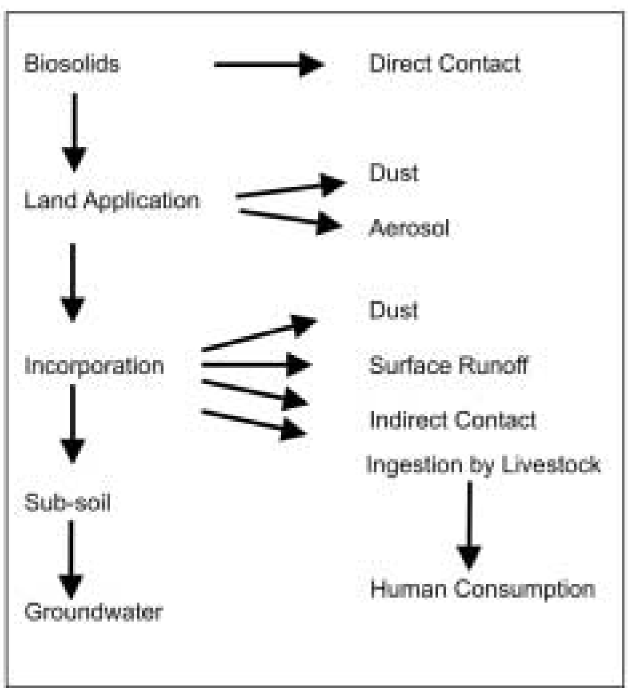
This report provides an overview of information about Group II contaminants identified in the WEAO study, as well as a look at identified emerging issues and human health studies that have been conducted related to biosolids. Each section focuses on the potential health effects of biosolids land application and exposure pathways.

Figure 1-1 is a simplified illustration of pathways of exposure from contaminants and pathogens in land-applied biosolids to people. While the literature reviewed is not specific about the potential means of exposure, generally speaking, exposure is possible via ingestion or inhalation, or by direct contact with broken skin.

In the case of the City of Ottawa biosolids land application program, exposure from biosolids may occur as a result of the following:

- Dispersion when biosolids are stockpiled in the field
- Dispersion during loading of spreaders
- Dispersion during spreading
- Direct contact with biosolids tracked on public roads
- Direct contact through public access to spread sites
- Movement to groundwater
- Ingestion by grazing livestock which are subsequently consumed by humans

FIGURE 1-1
Exposure Pathways or Pathogens (After Straub et al. 1993)



The section on pathogens (Section 3) discusses bacteria, viruses, and parasites. The section on unregulated metals (Section 4) covers the metals that currently are not regulated by the Ontario Ministry of the Environment. The section on estrogenic hormones and pharmaceuticals (Section 5) provides a summary of the limited information in this expanding area. The section on emerging issues (Section 6) discusses recent findings regarding polybrominated diphenyl ethers (flame retardants), and links between odours and health effects. The literature summary concludes with health studies in the area.

2. Pathogens

2.1 Background

A pathogen is a disease-producing agent or microorganism (Dorland's Pocket Medical Dictionary 1982). Infection by a pathogen requires contact between a pathogen and a susceptible host (Lilienfield and Stolley 1995). The likelihood of infection is affected by the following factors:

- Excretion of pathogens by infected individuals
- Environmental conditions that affect survival of the infectious agent
- Availability of a route of entry into a host (susceptible individual)
- The existence of alternate reservoirs of the infectious agent in the environment

An individual may or may not become infected, depending upon the following:

- Time of exposure
- Dose of exposure
- Availability of a route of entry
- Susceptibility of an individual, influenced by genetic and/or immunological factors

During primary treatment of sewage, solid matter (primary sludge) is settled out and removed. At this stage, microorganisms in the solids, along with parasite ova and spores, which tend to settle as well, are removed from the raw sewage.

In an experiment to determine the extent of virus association with sludge solids, Bitton et al. (1984) added suspensions of poliovirus 1 and echovirus 1 to liquid sludge samples. They reported that 92 percent of poliovirus and 21 percent of echovirus were observed to be associated with the sludge solids. They concluded that viruses were embedded in the sludge floc, and to a lesser extent were adsorbed. Straub et al. (1993) report in their literature review that viruses are adsorbed to the sludge flocs. Pathogens that do not associate with the solids or do not otherwise settle remain with the water fraction.

In the case of Ottawa's Pickard Centre, primary sludge represents approximately 65 percent of the solids going to the digesters. The remaining 35 percent is thickened waste-activated sludge, which is excess biomass grown through secondary treatment of the sewage (Robertson, 2002).

Anaerobic, mesophyllic biosolids[1] may contain pathogens that can be classified into four groups:

1. Bacteria – prokaryotic single celled microorganisms
2. Viruses – infectious agents that are able to replicate only within a living host cell, consisting of a nucleoid and a protein shell

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[1] "Biosolids," "Sewage Biosolids," and "Sewage Sludge" are used interchangeably, depending upon usage in the source being quoted.

3. Parasitic protozoa – single-celled parasitic microorganisms
4. Helminthes – parasitic worms

Table 2-1 lists microorganisms enumerated in Ottawa's biosolids cake. The diversity and number of pathogenic organisms in sewage biosolids reflects the general health of the contributing population (Smith, 1996). The numbers indicated in Table 2-1 for the City of Ottawa are typical of anaerobically digested, dewatered biosolids (Chauret et al., 1995). At this time, there are no regulatory limits for microorganisms in Ontario biosolids. Unlike bacteria, there are no normal flora of viruses in humans. However enough people are infected at any point in time to account for their presence in sewage (Cliver, 1980).

TABLE 2-1
Numbers of Various Microorganisms in Ottawa Biosolids
(Chauret et al. 1999) Note all numbers are reported as the count per 100 g wet weight for ten samples (Normally 30 percent solids)

Variable		Mean	Min	Max
Total Coliforms	Bacterial Indicator	4.06×10^{9}	1.20×10^{7}	6.20×10^{10}
Fecal Coliforms	Bacterial Indicator	3.07×10^{7}	3.00×10^{6}	8.20×10^{7}
Fecal Streptococci	Bacterial Indicator	6.81×10^{7}	2.00×10^{6}	3.90×10
Clostridium perfringens	Bacteria	9.25×10^{7}	2.60×10^{7}	1.84×10^{8}
Heterotrophic plate count	Bacterial Indicator	4.84×10^{9}	2.43×10^{8}	2.96×10^{10}
Somatic coliphages	Viral Indicator	9.8×10^{5}	1.74×10^{5}	3.04×10^{6}
Cryptosporadium parvum	Parasitic protozoa	1.84×10^{3}	<10	3.75×10^{3}
Giardia lamblia	Parasitic Protozoa	8.86×10^{3}	<10	2.82×10^{4}

The bacteria group *Salmonella* is considered to be the most prevalent group of human pathogens in biosolids. There are 1,800 to 2,000 different known serotypes of *Salmonella*, a large number of which are pathogenic to human (Carrington 1978, Smith 1996). Other bacteria that may be present in biosolids include *Escherichia coli.*, *Clostridium sp*, *Vibrio cholera*, *Staphylococcus sp* and *Streptococcus sp* (Straub et al. 1993, Arthur Anderson 2001). With respect to *E. coli.*, there reportedly are 164 known serotypes, very few of which are pathogenic to humans (Carrington 1978).

Cameron (1997) reported in a review of the literature that there is a relatively low risk of disease transfer from bacteria in land-applied sewage sludge. The infectious dose varies with each specific pathogen as well as with the route of infection and will be lower for children, the elderly, and the immuno-compromised (Block 1986).

2.2 Persistence and Survival of Pathogens in the Environment

When biosolids are land-applied, the reported survival of pathogens in soil is variable (Smith 1996, Straub et al. 1993, Carrington 1978, Engelbrecht 1978, Damgaard-Larsen et al.

1977, Cameron et al. 1977). Smith (1996) reported in a review of the literature that soil factors affecting the survival of pathogens include the following:

- Moisture content – greater survival in moist soils
- Temperature – longer survival at low temperatures
- pH – shorter survival in acidic soils
- Organic matter content – increased survival/re-growth with sufficient organic matter
- Permeability – shorter survival in sandy soils
- Antagonism from soil micro flora – increased survival in sterile soils

Soil may immobilize pathogens by filtration, by adsorption, and through natural die-off. Cameron (1997) reported in a review of the literature that in most cases, pathogens are retained in the top 1 cm of soil. In another literature review, Smith (1996) stated that, in general, microorganisms are retained in the surface soil layers by soil colloidal matter and that up to 97 percent of wastewater bacteria are retained in the top 1 cm of soil. Carrington (1978) reported that the rate of bacterial die-off in soil post-application is influenced primarily by meteorological factors. In Smith (1996), it is reported that bacteria numbers decline rapidly upon exposure to light, desiccation, and microbial antagonism when applied to soil in sludge. Freeze/thaw conditions also are detrimental to bacterial survival, while survival is enhanced in organic soils, likely from improved nutrient availability (Straub, et al. 1993). Cool, moist field conditions favour re-growth of indicator bacteria (Straub, et al.1993). Soil defense mechanisms such as microbial antagonism will cause bacterial die-off in sludge-amended soils (Engelbrecht 1978).

In Cameron et al. (1997), it is reported that that bacteria and virus numbers usually are reduced to a minimum in two to three months following application to soil, with survival at the upper end in moist, cool soils and at the shorter end in warm, dry soils. Straub, et al. (1993) reported *Vibrio cholera* survival of four to 10 days in soil. In Smith (1996), it is reported that a 90 percent reduction in *Salmonella sp.* can be expected within three weeks of application to soil. In some cases where high persistence times have been reported, there were high levels of bacteria inoculation (bacteria added to sludge) as well as prolonged, heavy applications of sludge to soil (Smith 1996).

Gibbs et al. (1997), reporting on research carried out in Australia, conclude that soil amended with biosolids should not be considered free of pathogens for at least a year post-application. The authors applied biosolids to test plots at a rate equivalent to 10 tonnes per hectare. The biosolids were incorporated following application. Prior to application, the biosolids samples were tested for indicator bacteria. Soil samples were collected from the test plots two weeks prior to biosolids application, immediately after application, and at increasing intervals for 37 weeks. Concentrations of the indicator bacteria dropped rapidly to below detection at between four and 12 weeks. However, concentrations of indicator bacteria were measured at greater levels than at the beginning of the trial at between weeks 29 and 36.

When interviewed as a part if this project, Goss explained that many of the factors in pathogen survival are not understood. Albin (1998) indicated that post-spreading survival of pathogens is variable and that bacillus and clostridia may produce spores that can be viable for decades. Viable but nonculturable (VBNC) bacteria may survive periods of nutritional or thermal stress. These organisms would not be detectable through traditional analytical methods (Albihn 1998).

Bitton et al. (1984) measured the survival of viruses in digested sludge-amended soil. The authors used lagooned sludge from a wastewater treatment plant in Florida that had been seeded with poliovirus 1. The sludge was added to the top of undisturbed soil cores and was exposed to ambient environmental conditions. They reported that poliovirus could be detected in fine sand soil for up to 35 days with the soil temperature ranging from 23.5°C to 29°C. At temperatures of 18°C to 27°C the survival was reported to be eight days. Sattar (1983) reported that lower temperature soils prolong viral infectivity in sludge-amended soils and that as soil temperature rises, it is not the temperature, but rather a more rapid loss of soil moisture and possibly an increase in the metabolic activities of soil microbiota that result in reduced survival of viruses.

Damgaard-Larsen et al. (1977) applied municipal sludge seeded with coxsackievirus B3 to the top of lysimeters at an experimental station in Denmark. The authors reported that it took 23 weeks during a normal Danish winter to inactivate coxsackievirus in sludge-amended soil. They concluded that virus inactivation, based on their results as well as on literature results, is a slow process under natural conditions. However, they also concluded that the viruses will tend to be retained in the topsoil.

Graham (1983) stated that parasite eggs have been recovered from many Ontario sewage sludges as well as from fields that have been amended with sewage sludge. The eggs reportedly can survive on pasture for several years, but only for a few weeks when mixed with the soil. Little (1980), in a literature review, reported incidents of parasite survival that range from several years to 15 years in one case. The possibility of transmission reportedly is greater in animals, if they graze on land that has been spread with biosolids.

2.3 Movement

Smith (1996) stated that pathogens are most likely to enter surface water or groundwater when they are applied on shallow, fine-textured soil over fissured bedrock, where there are preferential pathways down through the soil. Preferential pathways may include the following:

- Fissures in dried soil
- Worm holes
- Rodent holes

These preferential pathways represent the “path of least resistance” for downward movement of water through soil.

Yates and Yates (1991), in their discussion on modeling microbial transport in soil, indicated there are four primary processes involved in contaminant (microbial) transport:

- Decay – irreversible destruction/die-off
- Advection – movement with bulk soil water flow
- Dispersion – diffusion and mechanical mixing
- Adsorption – chemical binding with the surface of soil particles

According to Yates and Yates (1991), adsorption values will vary, depending upon the microorganism, and it may be reversible or irreversible, controlled by diffusion, or controlled by equilibrium. It is for this reason that Sattar (1983) recommended that the virus-retaining characteristics of individual soils should be assessed before a site is considered suitable for municipal seweage sludge disposal. The author does not specify how such an assessment would be carried out.

Straub et al. (1993) reported in their literature review that viruses are effectively retained in the soil matrix and that the viruses are adsorbed to the sludge flocs. Unless the sludge particles move through the soil, the viruses remain immobilized. Engelbrecht (1978) stated that the movement of viruses in soil, like that of bacteria, is directly related to the hydraulic infiltration rate and inversely to the particle size of the media.

In a review of the literature, Cameron (1997) reported that a travel distance of 15 to 30 meters is sufficient for removal of biological contaminants under saturated flow, while less than 3 meters is sufficient for removal of most biological contaminants in unsaturated soil. Engelbrecht (1978) reported that, while bacteria will not move more than 100 feet (30 meters) through granular soils, the upper layer of soil is most effective in removing bacteria. In Smith (1996), it was reported that a 3 cm soil column removed 99 percent of *salmonella* and 99.9 percent of *E. coli.* (the experimental method was not described).

Many enteric organisms may be transmitted effectively by aerosols (Straub et al. 1993). Dowd et al. (2000) reported that infective doses are lower for inhaled versus ingested enteric organisms.

Pillai et al. (1996) conducted a four-month monitoring study around an application site in Sierra Blanca Texas to determine whether municipal sewage sludge application resulted in the release of airborne bacterial pathogens. The authors concluded that, given the geographical and weather conditions present during their study, land-application of municipal sludge (at a rate of 6.7 dry tons/ha) posed little risk of airborne transmission of bacterial pathogens.

Dowd et al. (2000) (using data collected at the Sierra Blanca site and published previously) modeled airborne transport of bioaerosols. The quantified transport data was used in a dose-response model to characterize the risk of infection from pathogenic bacteria and viruses to workers and neighbouring residents. While cautioning that the microbial transport modeling and risk assessment represented a worst-case scenario and "should be only used for a broad assessment of potential problems associated with biosolids placement," Dowd's results indicated a relatively high risk of infection to workers and residents within 10 kilometres of a land-application site. For example, Dowd described a predicted risk of 0.218 with an eight-hour exposure, wind speed of 5m/s, and a distance from the spreading site of 500 meters. The results of Dowd's work are the subject of considerable debate. It is unclear whether the type of biosolids studied or the method of application used to generate the pathogen-release data are representative of management practices in Ottawa.

2.4 Management Implications

In Ontario, biosolids can be applied only on soil that is at least 1.5 meters deep, of which a minimum of 0.9 meters is unsaturated. Separation distances from wells range from 15 to 90 meters (Ministry of Environment and Ontario Ministry of Agriculture, Food and Riral Affairs, 1996). Based upon the literature summarized, best management practices are recommended to specify how the soil depth from bedrock should be determined and how and when the depth of unsaturated soil should be measured. Guidance on the separation distance from residential areas as well as public access to biosolids-amended fields also is provided.

The best management practices do not address the issue of tile-drained fields. The literature summarized does not address tile drains explicitly. The rapid movement of pathogens into tile drains through preferential pathways has been raised as a concern (City of Ottawa Environmental Services Committee 2001). Preferential pathways are of particular concern with liquid biosolids, which typically are a slurry of four to eight percent solids. However, in the case of Ottawa, where dewatered cake is land-applied (typically 30 percent solids), it could be argued that preferential pathways are not as significant an issue because of the following:

- Contaminants (including pathogens) are associated with the sludge solids in dewatered cake
- The dewatered solids likely do not re-dissolve in the soil water
- The dewatered solid particles are likely too large to move through preferential pathways
- Water moving through preferential pathways is less likely to leach contaminants from soil because soil/water contact is limited

The Biosolids Management Plan Update (2001) recommended further research on the effects of land-applying dewatered biosolids on tile drained fields to surface water quality.

2.5 References

Albin, A. *Hygienic aspects of organic waste use in agriculture*. Petersen J. and S.O. Petersen ed. Use of municipal organic waste – Proceedings of NJF seminar no. 292, Nov 1998.

Arthur Andersen. *Disposal and Recycling Routes for Sewage Sludge – Scientific and technical sub-committee report*. Report Prepared by Arthur Andersen for the European Commission DG Environment - B/2; 2001.

Bitton, G., O.C. Pancorbo and S.R. Farrah. *Virus Transport and Survival After Land Application of Sewage Sludge*. Appl. Env. Micro. 1984 ; 47:5 pp905-909.

Block, J.C. *Biological Health Risks of Sludge.* edited by Block, J.C.; Havelaar, A.H.; L'Hermite, P. Disposal Epidemiological Studies of Risks Associated with the Agricultural Use of Sewage Sludge: Knowledge and Needs. Elsevier Applied Science Publ. 1986.

Cameron, K.C., H.J. Di and R.G. McLaren. *Is soil an appropriate dumping ground for our wastes?* Aust. J. Soil Res. 1997; 35 pp995-1035.

Carrington, E.G. *The Contribution of Sewage Sludges to the Dissemination of Pathogenic Microorganisms in the Environment*. Technical Report TR71 Water Research Center, 1978.

CH2M HILL Canada Limited. *Final Report Biosolids Management Plan Update.* Prepared by CH2M HILL Canada Limited for the City of Ottawa; July 2001.

Chauret, C., R. Sharma, S. Springthorpe and S. Sattar. *The efficiency of the anaerobic digestion process in reducing pathogen content of treated sludge or biosolids*. Report for the Regional Municipality of Ottawa-Carleton ; 1995.

City of Ottawa Environmental Services Committee. Meeting Minutes. 27 November 2001.

Cliver D.O. *Agricultural Crops: Pathogens*. Health Risks of Land Application. Ann Arbor Science Publishing; 1980.

Damgaard-Larsen, S., K.O. Jensen, E. Lund and B. Nissen. *Survival and Movement of Enterovirus in Connection with Land Disposal of Sludges*. Water Research. 1977; Vol. 11 pp509-508.

Dorland's Pocket Medical Dictionary Twenty-Third Ed. W.B. Saunders Company; 1982.

Dowd, S.E., C.P. Gerba, I.L. Pepper and S.D. Pillai. *Bioaerosol Transport Modeling and Risk Assessment in Relation to Biosolids Placement*. J. Environ. Qual. 2000; 29 pp343-348.

Dumontet, S., A. Scopa, S. Kerje, and K. Krovacek. *The Importance of Pathogenic Organisms in Sewage and Sewage Sludge*. J. Air and Waste Manage. Assoc. 2001; 51 pp848-860.

Engelbrecht, R.S. *Microbial Hazards Associated with the Land Application of Wastewater and Sludge Public.* Health Engineer. 1978; 6(4) pp219-226.

Gibbs, R.A., C.J. Hu, G.E. Ho, I. Unkovich. *Regrowth of Fecal Coliforms and Salmonellae in Stored Biosolids and Soil Amended With Biosolids*. Wat. Sci. Tech. 1997; Vol. 35, No. 11-12 pp269-275.

Graham H.J. Parasites and the Land Application of Sewage Sludge in Ontario in Biological Health Risks of Sludge Disposal to Land in Cold Climates, edited by Wallis, P.M.; Lehmann, D.L.1983

Goss, Michael. Personal interview. 30 January 2002.

Lilienfeld, D.E. and P.D. Stolley. *Foundations of Epidemiology*, 3ed Ed. Oxford University Press; 1994.

Little, M.D. *Agents of Health Significance*. Sludge – Health Risks of Land Application. Ann Arbor Science Publishing; 1980.

Ministry of Environment and Energy and Ministry of Agriculture, Food and Rural Affairs. *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land.* Queen's Printer for Ontario; 1996.

Pillai S.D, K.W. Widmer, S.E. Dowd and S.C. Ricke. *Occurrence of Airborne Bacteria and Pathogen Indicators during Land Application of Sewage Sludge*. Appl. Env. Micro. Jan. 1996; pp296-299.

Roberston, David. Personal conversation. 2002.

Sattar S. A. *Viruses and Land Disposal of Sewage Sludge: A Literature Review.* Wallis, P.M.; Lehmann, D.L. eds. Biological Health Risks of Sludge Disposal to Land in Cold Climates. 1983.

Sekla, L., D.L. Lehmann and P.M. Wallis. *Parasites and the Application of Sewage: A Literature Review and Assessment of the Health Risk in Canada.* Wallis, P.M.; Lehmann, D.L. eds. Biological Health Risks of Sludge Disposal to Land in Cold Climates. 1983.

Smith, S.R. *Pathogenic Organisms in Agricultural Recycling of Sewage Sludge and the Environment*. CAB International, Wallingford, UK; 1996.

Straub, T.M., I.I. Pepper, and C.P. Gerba. *Hazards from Pathogenic Microorganisms in Land-Disposed Sewage Sludge*. Reviews of Environmental Contamination and Toxicology. 1993; Vol. 132.

Yates, M.V. and S.R. Yates. *Modeling Microbial Transport in the Subsurface: A Mathematical Discussion.* Hurst C.J. ed. Modeling the Environmental Fate of Microorganism. American Society for Microbiology; 1991.

3. Unregulated Metals and Inorganic Compounds

3.1 Background

There is a considerable volume of primary research published on the fate and effects of heavy metals in biosolids applied to land (WEAO 2000). The WEAO report (2000) indicates that much of this research pertains to the so-called 'regulated metals[2]', which includes most of the heavy metals. As such, they are classified as Group I by the WEAO report (see 1.2.1). The Group II, unregulated metals are those where the effects on human and animal health as well as plant phytotoxicity are less clear. Specifically, the following metals have been considered:

- Aluminum (Al)
- Antimony (Sb)
- Barium (Ba)
- Beryllium (Be)
- Boron (B)
- Fluoride (F-)
- Silver (Ag)
- Strontium (Sr)
- Thallium (Tl)
- Tin (Sn)
- Titanium (Ti)
- Vanadium (V)

Cyanide and asbestos were also identified. Generally, the concentrations of the unregulated metals in Ottawa's biosolids are at the low end of typical ranges seen in the US and the UK.

Based on a no-net-degradation approach (described below), silver and antimony may restrict biosolids application rates. However, based upon the limited data available, the concentrations of these metals in Ottawa's biosolids would not cause phytotoxic effects on plants or health effects on animals or humans.

3.2 Unregulated Metals Levels in Ottawa Biosolids

The Robert O. Pickard Environmental Centre analyses some of the unregulated metals in their biosolids cake on a weekly basis. Concentrations are provided as the mass of the metal per kilogram of total solids (TS) of biosolids, on a dry weight basis. Following is a summary of data obtained between January 3 and December 3 of 2001. No data is available on cyanide, asbestos or fluoride.

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[2] The regulated metals are: arsenic, cadmium, cobalt, chromium, copper, mercury, molybdenum, nickel, lead, selenium, and zinc

TABLE 3-1
Summary of Biosolids Cake Unregulated Metals Analyses at ROPEC

Unregulated Metal	Metal Concentration (mg/kg TS) Max	Min	Average	Metal Loading [2] (kg/ha/5yrs)
Aluminum (Al)	17,300	10,400	12,800	102.40
Antimony (Sb)[1]	16	<2	5.8	0.05
Barium (Ba)	670	340	492	3.94
Beryllium (Be)[1]	32	23	25.5	0.2
Boron (B)[1]	11	4.2	7.8	0.06
Silver (Ag)	41	22	34	0.27
Strontium (Sr)	830	450	618	4.94
Thallium (Tl)[1]	nd	nd	nd	nd
Tin (Sn)[1]	62	28	38	0.30
Titanium (Ti)	150	36	71	0.57
Vanadium (V)	21	6	14	0.11

[1] Results very close to or below method detection limits (MDL); data within 2 to 4 times the MDL are not considered to be significantly different

[2] Average metal loadings are based on the maximum application rate of 8 dry tonnes of biosolids per hectare per 5 years at the average concentration.

3.3 No-Net-Degradation-Method Limits

The no-net-degradation-method limits are based on not increasing soil metal concentrations by more than two to four times the normal background levels. The allowable increase in soil concentration is two times for metals that are not essential for crop growth and four times for metals that are essential elements for crop production.

Background levels were developed by determining 98th percentile concentrations from an Ontario-wide sampling program at rural and urban parks that are unaffected by local point sources of pollution.

Table 3-2 represents metals that were investigated in the WEAO study and that are included in the Group II list of unregulated metals and compares them with the background levels, typical Canadian biosolids concentrations, and Ottawa biosolids concentrations. The maximum number of biosolids applications that do not exceed the maximum permissible loadings in Ontario was determined.

TABLE 3-2
Background Approach Limits in Ontario for Unregulated Metals (where data is available)[3]

Unregulated Metal	Background Soil Approach Limits (mg/kg dry wt)	Canadian Biosolids Maximum Concentration (mg/kg dry wt)	Ottawa Biosolids Maximum Concentration (mg/kg dry wt)	Maximum Permissible Loading (kg/ha)	Maximum Number of Biosolids Applications[1]
Antimony (Sb)	1.0	117	16	1.6	12
Barium (Ba)	190	688	670	230	42
Beryllium (Be)	1.2	<1.5, 30 [2]	32	1.5	5
Silver (Ag)	0.35	81	41	0.46	1
Thallium (Tl)	2.5	131	nd	4.0	

[1] Total number of applications at one site based on a maximum permissible biosolids application rate of 8 dry tonnes/ha/5 years using the maximum Ottawa concentrations. For example, for Sb would limit the biosolids program to 12 applications over a period of 60 years.

[2] Canadian data not available, values are for U.S. and U.K. respectively.

[3] Taken from WEAO, April 2001

Based on this approach, silver is the most restrictive and it limits the number of biosolids applications to one for a typical site (two, based on Ottawa biosolids silver concentration). Based on soil phytotoxicity values, the silver loadings would be much less restrictive.

3.4 Significance of Unregulated Metals

The unregulated metals are contained in the raw sewage treated at the wastewater treatment plant. They tend to associate with the solids during wastewater treatment and become concentrated in the biosolids at low levels. Sources include residential, commercial/institutional, and industrial discharges to the sewer collection system.

Industrial source control, with municipal sewer use bylaws, limits the discharges of regulated metals to the sewer. The typical industrial sources, removal rates in wastewater treatment plants, levels in the biosolids, and potential effects on plants, animals, and humans are discussed below. Typical industrial sources also are included in Appendix C, Table C-2 . Removal rates at the Pickard Centre are included in Appendix C, Table C-3. Fates of the metals in the environment are discussed in Appendix C, Table C-4.

3.4.1 Aluminum (Al)

Aluminum (Al) is the third most abundant element, accounting for 8.1 percent of the earth's crust by weight (Sparling and Lowe 1996). Aluminum sources include metal alloy manufacturing, castings, construction materials, paper manufacturing, and aluminum sulphate (alum), which is used in Ottawa's water purification plants. More than 90 percent of the aluminum in raw wastewater typically is removed during liquids treatment and become concentrated in biosolids. Ottawa's biosolids mean aluminum concentration of 12,800 mg/kg TS is at the median of the typical range in biosolids. Typical ranges are 8,100 to 51,200 mg/kg TS, with a median concentration of 14,000 mg/kg TS (Lester 1987). The typical ranges are based on several types of biosolids, including anaerobic and aerobically digested biosolids, as well as biosolids from primary and secondary treatment plants.

The aluminium concentrations are well below levels of concern identified in other jurisdictions. The Dutch Chemical Waste Act (CWA) specifies that materials with less than 50,000 mg AL / kg TS would not be considered a waste and would be unregulated.

Available soil phosphorus may be reduced with increasing amounts of available aluminum. Aluminum uptake is pH- and plant-species-dependent. In acidic soils, aluminum levels are greater in roots and older leaves than in younger foliage (Will and Suter 1995a).

Aluminum interferes with cell division in roots; decreases root respiration; fixes phosphorous in unavailable forms in roots; interferes with uptake, transport, and use of calcium, magnesium, phosphorous, potassium, and water; and interferes with enzyme activities (Foy et al. 1978). Symptoms of toxicity include stubby, coralloid, damaged, and brittle roots, stunting, late maturity, collapse of growing points, purpling of stems, death of leaf tips, and dark green leaves (Aller et al. 1990). Such damage to the roots inhibits water and nutrient absorption. Seedlings are more susceptible to damage from Al toxicity than are older plants.

Relative to other metals, the animal toxicity of aluminum is low (Sorensen et al. 1974). The principal effect of aluminum is to interfere with phosphorous metabolism. In the alimentary canal, aluminum forms insoluble compounds with phosphorous, resulting in an imbalance of calcium and phosphorous (Carriere et al. 1986). Other effects of aluminum include neurotoxicity.

3.4.2 Antimony (Sb)

Antimony is used in metallurgical processes, paints and enamels, various textiles, rubber, and fire retardation (antimony trioxide). No data on antimony removals in wastewater treatment systems are available. Ottawa's biosolids mean antimony concentration of 5.8 mg/kg TS is at the low end of the typical range in biosolids. Typical ranges are 3 to 44 mg/kg TS, with median concentrations of 10 mg/kg TS (Lester 1987).

Antimony has been identified as being potentially toxic in agricultural soils (Beckett, 1976). Antimony is considered a nonessential metal and is easily taken up by plants if available in the soil in soluble forms (Kabata-Pendias and Pendias 1984).

Germany is the only jurisdiction known to regulate antimony. The maximum soil concentration limit is 5 mg/kg. After incorporation into the soil, Ottawa's biosolids would increase soil antimony concentrations on average by less than 0.1 mg/kg per application.

Antimony is regulated in drinking waters in the US, but has not been identified by the Canadian Council of Ministers of the Environment (CCME) for regulation of agricultural uses, including application to crops (CCME, 1984). No information is available on the phytotoxic effects of antimony.

Antimony effects at high exposures in animals appear to be on the gastrointestinal tract (irritation, diarrhea, vomiting), blood (hematological disorders), and liver (mild hepatotoxicity) (ATSDR 1990).

3.4.3 Barium (Ba)

Barium has industrial applications in areas such as paper manufacturing, fabric printing and dyeing, synthetic rubber production, and drilling fluids (see Table C-2). Most of the barium entering the Pickard Centre would be removed and concentrated in the biosolids (see Table C-3 in Appendix C). Ottawa's mean barium concentration of 492 mg/kg TS is at the low end of the typical range in biosolids. Typical ranges are 272 to 1,066 mg/kg TS, with median concentrations of 539 mg/kg TS (Lester 1987).

Barium is regulated in drinking waters in the US, Europe and USSR. It is not regulated in drinking water in Canada and has not been identified by the CCME for regulation of agricultural uses (CCME 1984).

Barium has been identified as being potentially toxic to plants in agricultural soils (Beckett 1976). Barium is commonly present in plants but is not an essential component of plant tissues. It is taken up easily from acid soils (Kabata-Pendias and Pendias 1984). Mechanisms of toxicity may include competition with Ca for root uptake (Wallace and Romney 1971).

At low doses, barium acts as a muscle stimulant and at higher doses affects the nervous system of mammals, eventually leading to paralysis. The LD50 for rats is 630 mg/kg for barium carbonate, 118 mg/kg for barium chloride, and 921 mg/kg for barium acetate (Lewis and Sweet 1984).

3.3.4 Beryllium (Be)

Background

Beryllium, an alkaline earth metal, is experimentally used as a missile propellant, in metal alloys, x-ray tubes, in the nuclear industry and other industrial purposes (Finch et al 1990; Oehme 1979). Greater than 50 percent of the beryllium typically is removed and concentrated in the biosolids. Ottawa's mean biosolids beryllium concentration of 25.5 mg/kg TS is at the high end of the typical range in biosolids. Typical ranges are 1 to 30 mg/kg TS, with median concentrations of 3 mg/kg TS (Lester, 1987). Beryllium concentrations in biosolids typically are similar to soil concentrations (Lester, 1987). Concentrations may increase slightly with biosolids application as biosolids organic matter is degraded and mineralization occurs.

Beryllium has been identified as being potentially toxic to plants in agricultural soils (Beckett 1976). However, beryllium concentration limits in soil or loadings to soil have not been identified in Europe, the US, or Canada. Germany has identified a maximum beryllium soil concentration of 10 mg/kg. After incorporation into the soil, Ottawa's biosolids would increase soil beryllium concentrations on average by less than 0.2 mg/kg per application.

Beryllium can impact plant growth, particularly in acid soils (Williams 1968). Effects were not observed in alkaline soils. Kloke (1979) reported unspecified toxic effects on plants grown in a surface soil with the addition of 10 mg Be/kg. Be has been reported to inhibit seed germination, enzyme activation, and uptake of calcium and magnesium by roots. Common symptoms are brown, retarded roots, and stunted foliage (Romney and Childress 1965).

Beryllium is considered phytotoxic when plant tissue levels are greater than 0.6 mg/kg (Lester, 1987). However, beryllium is not readily transported into plant foliage (Gough 1979). Soluble forms of Be are easily taken up by plants, probably in a manner similar to Ca and Mg, but it is not readily translocated from roots to shoots (Peterson and Girling 1981).

For livestock, beryllium may be toxic as well as carcinogenic and has the potential to bioaccumulate (USEPA 1980). Effects from cattle ingestion of biosolids are not available.

3.3.4 Boron (B)

Boron has medicinal properties as sodium borate, and borax is used as a common cleaner (Dixon et al.,1976). Borax ($Na_2B_4O_7$) is alsoused in soldering and welding to remove oxide film, for softening water, in soaps, and in glass, pottery, and enamels. Agricultural runoff from the application of boric acid as an insecticide and non-selective herbicide acts as a non-point source that severely affects the ecology of wetlands (Sander et al. 1991; Smith and Anders 1989). Boron is essential to plants (Smith and Anders 1989). Boron also can be found in vegetables, fruits, cereals, and breads (Lee et al. 1978).

Boron is poorly removed from wastewater in wastewater treatment plants. The majority of the boron is discharged with the effluent. However, boron is present in biosolids. Ottawa's mean biosolids boron concentration of 7.8 mg/kg TS is at the low end of the typical range in biosolids. Typical ranges are 15 to 1,000 mg/kg TS, with median concentrations of 50 mg/kg TS (Lester, 1987). For comparison, in soils, boron (B) typically is found in concentrations ranging from 10 to 300 mg/kg, with an average concentration of 16 mg/kg (Oehme 1979).

Boron is not usually regulated in biosolids, since the concentrations typically are lower than levels of concern. Boron is regulated in municipal solid waste (MSW) composts and other organic materials, where boron concentrations may be much higher (Logan 1999).

Ontario regulates boron loadings to soil for organic wastes other than biosolids. Boron limits are less than 1 kg/ha/yr for boron-intolerant crops and 2 kg/ha/yr for boron-tolerant crops. (MOE / OMAFRA 1996). UK limits for boron addition to soil are a maximum of 3.5 kg/ha per year (Lester 1987). Boron applications with ROPEC's biosolids typically would be less than 0.1 kg/ha.

Boron is an essential nutrient for plants, with uptake proportional to the boron concentration in the soil (Moseman 1994), becoming highly toxic at elevated levels (Butterwick et al. 1989). Boron effects on corn seedlings growth has been observed at 50 mg/kg soil concentrations in muck soils (pH 4.5; 56 percent organic matter), and silt loam soils (pH 5.7; 3 percent organic matter) (10 mg/kg had no effect). Symptoms of boron toxicity include yellowing of leaf tip, chlorosis, necrosis of chlorotic tissue, and leaf abscisis (Butterwick et al. 1989).

Boron is a plant micronutrient involved in transport of sugars across membranes, synthesis of nucleic acids, and protein use. It is rapidly taken up, mainly as the neutral $B(OH)_3$ molecule and equally distributed between roots and shoots (Wallace and Romney 1977). Grasses and legumes appear to have greater than average tolerance to high B concentrations (Gupta 1984), and pine trees appear to be particularly sensitive (Stone and Baird 1956).

According to the USEPA, 5.0 mg B/L in drinking water is the maximum safe level of boron for livestock (Butterwick et al. 1989). Sheep develop enteritis with naturally occurring boron at concentrations of 130-300 mg B kg/L (Koval'skii 1965, as cited in Butterwick et al. 1989). Sisk et al. (1990) fed goats 2.0g/kg BW of a boron fertilizer that had proven toxic to cows, and observed behavioral effects that included stargazing (staring), spontaneous charging, avoidance behavior from phantom attacks, tail-wagging, and prancing after 40-48 hours post-exposure. 48-72 hours post-exposure they had hung heads, tremors, ear flicking, and head jerking, and showed signs of anorexia (Sisk et al. 1990).

3.3.5 Fluoride (F-)

Fluorides are used in metallurgical processes, semiconductor manufacturing, phosphate fertilizers, insecticides, and herbicides, and in refining uranium ores. It is added to Ottawa's domestic water supplies to reduce dental cavities.

There is no fluoride data on Ottawa's biosolids. However, the guidelines for limits in sewage sludge applied to agricultural land in the UK are 20 kg/ha per year (Lester 1987). This corresponds to a maximum concentration of 2500 mg/kg TS at a maximum application rate of 8 tonnes/ha in one application.

In agriculture, fluorides have been reported to cause damage to roots of barley plants (Bale 1973) and damage to foliage to some types of plants (Conover 1971). For human and animal health, fluorides have been shown to improve resistance to tooth decay at low concentrations. No toxic effects at concentrations below 50 mg/kg in dietary feeds have been observed (Said 1977). At high concentrations, fluorides have resulted in tooth damage, bone lesions, and retarded weight gains.

3.3.6 Silver (Ag)

Silver is a naturally occurring element commonly found in the rocks and minerals of the earth's crust. Emissions from smelting operations, manufacture and disposal of photographic and electrical supplies, and coal combustion are some of the sources of silver to wastewater treatment plants (Freeman 1979).

Approximately 38 percent of the silver is removed from wastewater during treatment and concentrates in the biosolids. Silver in biosolids is mostly adsorbed to large organic particles during wastewater treatment (Lester 1987). Ottawa's mean biosolids silver concentration of 34 mg/kg TS is at the median of the typical range in biosolids in the UK. Typical ranges are between 5 and 150 mg/kg TS with median concentrations of 20 mg/kg TS (Lester 1987).

The silver concentrations and loadings are well below levels of concern identified in other jurisdictions. The Dutch Chemical Waste Act specifies that materials with less than 5,000 mg / kg TS would not be considered a waste and would be unregulated.

Missouri has guidelines limiting silver application to farmland to 224 kg/ha (200 lbs/ac). Silver applications with Ottawa's biosolids would be about 0.2 kg/ha per 5 years.

The solubility of the silver in biosolids is low. Leachate extracts from several biosolids samples under acidic conditions resulted in less than 0.02 mg/L in the leachate, less than the Canadian drinking water objectives of 0.05 mg/L to protect human health (Lue Hing 1985). As pH increases, silver solubility increases, and subsequently mobility increases.

Silver has been identified as potentially toxic in agricultural soils (Beckett 1978), primarily because of the higher concentrations in biosolids than in the soil. Silver is known to be toxic to aquatic life and would be inhibitory to wastewater treatment activated-sludge organisms at concentrations as low as 0.25 mg/L (depending on the form of the metal). Silver is regulated in receiving waters and drinking waters but not in biosolids applied to land. Silver is known to be phytotoxic when plant tissue levels exceed 4 mg/kg (Lester 1987). However, little information is available on plant uptake from soils at different concentrations, pHs, organic matter contents for different types of plants.

Smith and Carson concluded the toxicity arising from exposure of humans to silver was unlikely to pose a significant threat, because of the poor absorption and retention of ingested silver by humans. Silver toxicities are related to the speciation of the silver. Silver nitrates are very toxic, whereas silver chlorides and silver sulphides are two to four orders of magnitude less toxic (CCME 1987).

3.3.7 Strontium (Sr)

Background

Strontium sources include medicine, ceramics, and pyrotechnics. Strontium is poorly removed in wastewater treatment plants, with more than 80 percent discharged in the effluent. The remaining 20 percent is concentrated in the biosolids. Ottawa's mean biosolids strontium concentration of 618 mg/kg TS is at the low end of the typical range of biosolids in the UK. However, it is considerably higher than the typical median (Lester 1987). Typical ranges are between 80 and 2,000 mg/kg TS, with median concentrations of 300 mg/kg TS.

Strontium concentrations in biosolids are similar to the concentrations in soils. For comparison, the mean level of strontium found in the earth's crust is 450 mg/kg (Oehme 1979). Concentrations in soil may increase slightly with biosolids application after a long period of time as biosolids organic matter is degraded and mineralization occurs.

Strontium is regulated in drinking waters in the USSR, but has not been identified as a concern by the CCME for regulation of drinking waters, receiving waters, or agricultural uses, including application to crops and when ingested by livestock (CCME 1984). Also, no information is available on the phytotoxic effects of strontium.

Research indicates that Sr may inhibit calcium absorption in animals, leading to decreased calcium binding protein production (Omdahl and de Luca 1972). However, research on rats at dosages of up to 4800 mg/kg $SrCl_2$ showed no effects.

3.3.8 Thallium (Tl)

Background

Industrial uses of thallium include alloys, electronic devices, special glass and explosives (Zitko 1975). In wastewater treatment, typically about 70 percent of the thallium is removed from the wastewater and concentrated in the biosolids. Thallium is not detected in Ottawa's biosolids (average detection limit is 10 mg/kg). Concentrations in other surveys ranged from 0.1 to 89 mg/kg TS, with a mean concentration of 26 mg/kg TS.

Thallium has been identified as being potentially toxic in agricultural soils (Beckett 1976). However, thallium concentration limits in soil or loadings to soil have not been identified in Europe, the US, or Canada. Thallium is not considered phytotoxic when plant tissue levels are less than 20 mg/kg (Lester 1987), higher than Ottawa's biosolids concentration.

Few data were found showing toxicity of thallium to plants grown in soil. No effects on seed germination of radish, cabbage, turnip, lettuce, wheat, or millet were found at dosages of up to 40 mg/kg as Tl_2SO_4 in hydroponic solutions that were observed by Carlson et al. (1991).

Thallium is not essential for plant growth. Soluble thallium is readily taken up by plants and translocated to shoot parts, probably because of its chemical similarity to K. Toxic effects on plants include impairment of chlorophyll synthesis and seed germination, reduced transpiration because of interference in stomatal processes, growth reduction, stunting of roots, and leaf chlorosis (Adriano 1986).

Thallium can have toxic effects on aquatic organisms, animals, and humans. However, there is little evidence of human health effects from current environmental levels (Smith 1977). The CCME has not established limits for agricultural uses (CCME 1984).

Thallium sulfate, which has been widely used as a rodenticide, is acutely toxic to rats at dosages greater than 10 mg/kg. Because of this type of rodenticide's high toxicity to larger mammals, its use against larger predatory animals was banned in 1972 (Zitko 1975).

3.3.9 Tin (Sn)

Background

Industrial uses of tin include use in corrosion control, electrical condensers, bottle cap liners, food packaging, and fuses. In wastewater treatment, removals from wastewater typically range from 0 percent to more than 90 percent. Ottawa's mean biosolids tin concentration of 38 mg/kg TS is at the low end of the typical range in biosolids in the UK (Lester 1987). Typical ranges are between 40 and 700 mg/kg TS, with median concentrations of 120 mg/kg TS.

Germany limits the tin concentration in soil to a maximum concentration of 50 mg/kg, higher than Ottawa's biosolids tin concentration.

Missouri guidelines limit tin cumulative loadings to less than 1,120 kg/ha (1000 lbs/ac). At Ottawa biosolids application rates of 0.3 kg/ha per five years, biosolids application would not be limited by tin loadings.

Tin is not considered phytotoxic when plant tissue levels are less than 60 mg/kg (Lester 1987). Tin has not been identified as a concern by the CCME for agricultural uses (CCME, 1984).

3.3.10 Titanium (Ti)

Industrial uses of titanium include use in mining and smelting, manufacture of pigments, and paper manufacturing. No data are available on typical removals of titanium in wastewater treatment plants. Ottawa's biosolids titanium concentration of 71 mg/kg TS is well below the typical range in biosolids in the UK (Lester 1987). Typical ranges are between 1,000 and 4,500 mg/kg TS with median concentrations of 2,000 mg/kg TS.

Titanium has not been identified as a concern by the CCME for agricultural uses (CCME 1984). Titanium is not considered to be an essential element for either plants or animals. Titanium is known to have potential deleterious effects, but the effects have not been observed except in special circumstances (Lester 1987).

3.3.11 Vanadium (V)

Sources of vanadium collected in raw wastewater include burning fossil fuels, manufacturing pigments, the process of hardening steel, photography chemicals, and insecticides (Hudson 1964, and Hammond and Beliles 1980; as cited in Domingo et al. 1985). Vanadium removals from wastewater in treatment plants are typically low, with more than 75 percent of the vanadium discharged in the effluent. Vanadium is present in biosolids at low concentrations. Ottawa's biosolids vanadium concentration of 14 mg/kg TS is at the low end of the typical range in biosolids in the UK (Lester JN 1987). Typical ranges are between 20 and 400 mg/kg TS with median concentrations of 60 mg/kg TS.

The vanadium concentrations and loadings are well below levels of concern identified in other jurisdictions. The Dutch Chemical Waste Act specifies that materials with less than 5,000 mg / kg TS would not be considered a waste and would be unregulated.

Vanadium has been identified as potentially toxic in agricultural soils (Beckett 1978, Lester 1987). Vascular plants do not require vanadium for growth. At high concentrations, vanadium interferes with the uptake of essential elements such as calcium, copper, iron, manganese, and phosphorus (Wallace 1977). Phytotoxicity, the inhibition of plant growth, appears when vanadium soil concentrations in soil exceed 10 mg/kg, depending on soil type and species of plant (Hopkins 1977). Kloke (1979) reported unspecified toxic effects on plants grown in a surface soil with the addition of 50 mg/kg V. Therefore, after incorporation of Ottawa's biosolids into the soil, vanadium concentrations would be well below phytotoxic limits.

Vanadium is not known to be essential for plant growth, although it may be involved in N_2 fixation in nodules of legume roots. Toxicity symptoms include chlorosis, dwarfing, and inhibited root growth (Pratt 1966). Vanadium inhibits various enzyme systems while stimulating others, the overall effect on plant growth being negative (Peterson and Girling 1981). After uptake, it remains in the root system in insoluble form with Ca (Wallace and Romney 1977).

Vanadium toxicity is related to the speciation and solubility. However limited information on speciation and solubility in biosolids is available. Vanadium oxides are relatively inert when bound to aluminum and iron oxides present in the soil. Pentavalent NH_4VO_3 has been reported to be more than twice as toxic as trivalent VCl_3 and more than six times as toxic as divalent VI_2. Vanadium solubility and mobility increases at higher pHs.

For animals, research suggests vanadium is an essential element in animal diets, for lipid, tooth, and bone metabolism (Hopkins 1974). However, at high concentrations vanadium induced reduced growth rates and impairment of reflexes (Vanzinderan 1980). Other potential effects to animals with ingestion of high concentrations of vanadium include diarrhea, altered renal function, and decreases in erythrocyte counts, hemoglobin, and hematocrit (Domingo et al. 1985a, Zaporowska and Wasilewski 1991). Sheep were given dietary doses of vanadium at 10-800 mg/kg. Animals with the two highest doses, 400 and 800 mg/kg, more than 100 times the biosolids concentrations, ceased eating after one day and had excessive diarrhea.

For humans, epidemiological studies have correlated forms of heart disease and cancer with airborne vanadium. However, few studies have evaluated the potential health effects of vanadium in water and soil (Lester, 1987).

Vanadium is involved in lipid metabolism and may suppress cholesterol biosynthesis (Azarnoff et al. 1961, as cited in Carlton et al. 1982). Vanadium functions as a regulator of Na and ATPase (adenosoine triphosphatase), thus having great influence upon the sodium pump (Witkowska et al. 1988).

3.4 Movement

Soil properties that affect the reactions and resultant plant uptake of sewage sludge constituents include pH, organic matter, cation exchange capacity, iron and aluminum oxides, texture, aeration, specific sorption sites, and water availability (Page, et al. 1985).

In Ontario, soil pH must be maintained above 6.0 to prevent metal leaching where biosolids are land applied. Movement of metals as soluble metal-organic complexes has been identified as a concern. The speciation (form) of the metal governs the movement in soil and the metal's impact on water quality. Leachability of some metals, such as beryllium and barium, is a concern, particularly in acid sandy soils. Speciation of unregulated metals in biosolids is not well known and warrants further study.

3.6 References

Abuzkhar, A.A., A.S. Gibali, Y.I. Elmehrik, Rahmatullah. *Chemical Monitoring of Sewage Wastes for their Use in Crop Production*. Environ. Monit. Assess. 1987; v 8 n 2 pp127-133.

Adriano, D.C. *Trace Elements in the Terrestrial Environment*. Springer-Verlag, New York. 1986.

Arnold, K. J.H. Dunn, and D. Sievers. Biosolids standards for metals and other trace substances. http://muextension.missouri.deu/xplor/envqual/wq0425. Htm (viewed March 15, 2002).

Barry, G.A., P.J. Chudek, E.K. Best, and P.W. Moody. *Estimating Sludge Application Rates to Land Based on Heavy Metal and Phosphorus Sorption Characteristics of Soil*. Water Res. 1995; v 29 n 9 pp2031-2034.

Beckett, P.H.T., R.D. Davis, and P.Brindley. *The disposal of sewage sludge onto farmland: the scope of the problem of toxic elements*. Water Pollut. Control. 1979;78,419.

Butterwick, L., N. de Oude, and K. Raymond. *Safety assessment of boron in aquatic and terrestrial environments*. Ecotoxicol. Environ. Saf. 1989; pp339-371.

CCME. *Canadian Water Quality Guidelines*. Task Force on Water Quality Guidelines of the Canadian Council of Resource and Environment Ministers. 1987.

CEP Consultants. *Management & Control of Heavy Metals in the Environment*. International conference: Management & control of heavy metals in the environment, London, England. 1979; pp664.

CH2M HILL Canada Limited. *Trail Road Leachate Quality Comparison.* May 16, 2000.

Cohen, D.B., M.D. Webber, and D.N. Bryant. *Land application of chemical sewage sludge – lysimeter studies*. Ontario Ministry of Environment Sludge Utilization & Disposal Conference, Toronto. 1978; pp108(30).

Council for Agricultural Science and Technology. *Application of Sewage of Sludge to Cropland – Appraisal of Potential Hazards of the Heavy Metals to Plants and Animals.* US EPA / Office of Water Program Operations. 1976.

Edwards, D.R., P.A. Moore Jr., S.R. Workman, and E.L. Bushee. *Runoff of metals from alum-treated horse manure and municipal sludge*. Journal of the American Water Resources Association. 1999; c 35 n 1 pp155-165.

Efroymson, R.A., M.E. Will, G.W. Suter II and A.C. Wooten. *Toxicological Benchmarks for Screening Contaminants of Potential concern for Effects on Terrestrial Plant: 1997 Revision*. U.S. Department of Energy, office of Environmental Management. 1997.

Efroymson, R.A., M.E. Will, G.W. Suter, II, and A.C. Wooten. *Toxicological benchmarks for screening contaminants of potential concern for effects on terrestrial plants: 1997 Revision*. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 1997a; pp128.

Efroymson, R.A., M.E, Will, and G.W. Suter, II. *Toxicological benchmarks for contaminants of potential concern for effects on soil and litter invertebrates and heterotrophic processes: 1997 Revision*. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 1997b.

EPA. *Preliminary Investigation of Effects of Boron, Indium, Nickel, Selenium, Tin, Vanadium, and Their Compounds*, Vol. VI, Vanadium. U.S. EPA Report No. EPA-560/2-75-005f. Cited in EPA. 1980. A Screening Procedure for the Impacts of Air Pollution Sources on Plants, Soils, and Animals. EPA 450/2-81-078. Washington, D.C. 1975.

Foy, C.D., R.L. Chaney, and M.C. White. *The physiology of metal toxicity in plants*. Ann. Review Plant Physiol. 1978; v 29 pp511-566.

Freeman, R. *Ecological kinetics of silver in the alpine lake ecosystem, in Aquatic toxicology; Proceedings of the second annual symposium on aquatic toxicology*. ASTM Special Technical Publication 667. American Society for Testing and Materials, Philadelphia. L.L. Marking and R.A. Kimerle, editors. 1979; pp342-358.

Gough, L.P., H.T. Shacklette, and A.A. Case. *Element concentrations toxic to plants, animals and man*. U.S. Geol. Surv. Bull. 1466. 1979.

Gupta, U.C. *Boron nutrition of alfalfa, red clover, and timothy grown on podzol soils of eastern Canada*. 1984; v 137 n 1 pp16-22.

Hartenstein, R., A.L Leaf, E.F. Neuhauser, and D.H. Bickelhaupt. *Composition of the earthworm Eisenia foetida (Savigny) and assimilation of 15 elements from sludge during growth*. Comparative Biochemistry and Physiology. 1980: pp187-192.

Inyang, A.D. *Environmental distribution of Co, Cr, Fe, Pb and Mn after land application of undigested municipal wastewater sludges*. University of Missouri Trace Subst in Environ Health 19th Conference, Columbia. 1985; pp425(10).

Inyang, A.D. *Environmental transport of heavy metals from soil amended with undigested sludge*. Diss. Abst. Int. Pt. B. Sci & Eng. 1982; v 43 n 1 pp165.

Jukes, G. *Environmental Health and the Public's Perception of Sewage Sludge Disposal.* Anglian Water Conference on "The Sustainable Use of Sewage Sludge", Oakham, Rutland, July 3, 1997. http://www.cieh.org.uk/about/policy/papers/sludge.htm (viewed January 2, 2002).

Kabata-Pendias, A., and H. Pendias. *Trace Elements in Soils and Plants*. CRC Press, Inc. Boca Raton, Florida. 1984.

Kloke, A. *Content of arsenic, cadmium, chromium, fluorine, lead, mercury, and nickel in plants grown on contaminated soil*. Paper presented at United Nations-ECE Symp. Effects of Air-borne Pollution on Vegetation. Warsaw. in: A. Kabata-Pendias and H. Pendias (eds.). 1984. Trace Elements in Soils and Plants. CRC Press, Inc. Boca Raton, Florida. 1979.

Knectel, R. *The Analysis of Chemical Digester Sludges for Metals by several Laboratory Groups*. Canada / Ontario Agreements on Great Lakes Water Quality. Microfiche.

Koval'skii, V. *Boron biogeochemical province of North Western Kazakhstan. Agrokhimiya*. 1965; pp153-169.

Lang, F., F. Bingman, F. Hendrix, and N. Crane. *Boron deposition on soil and native vegetation from geothermal emissions*. J. Environ. Qual. 1986; v 15 n 3 pp260-264.

Lee, I., J. Sherins , and R. Dixon. *Evidence for induction of germinal aplasia in male rats by environmental exposure to boron*. Toxicol. Appl. Pharmacol. 1978; v 45 pp577-590.

Lester, J.N. *Heavy Metals in Wastewater and Sludge Treatment Processes, Volume II: Treatment and Disposal*. CRC Press, Inc. 1987; pp95-96.

Lewis and Sweet. *Registry of toxic effects of chemical substances, 1983 supplement to the 1981-2 edition.* Governmental Reports Announcements and Index. 1984; v 9.

Logan, T.J., C.L. Henry, J.L. Schnoor, M. Overcash, and D.C. McAvoy. *Assessment of Health and Environmental Risks of Trace Elements and Toxic Organics in Land-Applied Municipal Solid Waste Compost*. Compost Science and Utilization. 1999; v 7 n 3 pp38-53.

Logan, T.J., C.L. Henry, J.L. Schnoor, M. Overcash, D.C. McAvoy. *Assessment of Health and Environmental Risks of Trace Elements and Toxic Organics in Land-Applied Municipal Solids Waste Compost*. Compost Science and Utilization. 1999; v 7 n 3 pp38-53.

Lucas, J.B., H.R. Pahren, and J.A. Ryan. *The Impact of Metals Present in Municipal Sludges Upon the Human Food Chain - A Risk Assessment*. EPA, Health Effects Research Lab., Cincinnati. Risk assessment and health effects of land application of municipal wastewater and sludges.

San Antonio, Tex. Dec. 12-14, 1977. Conference proceedings. Edited by B. P. Sagik and C. A. Sorber. 1978; pp132-140.

Lue-Hing, C., D.T. Lordi, D.R. Zenz, J.R. Peterson, and T.B.S. Prakasam. *Occurrence and fate of constituents in municipal sludge applied to land*. 1985; pp101-149.

Luoma, S.N., and E.A. Jenne. *The availability of sediment bound cobalt, silver and zing to a deposit feeding clam*. 1977.

Ministry of Environment and Energy and Ministry of Agriculture, Food and Rural Affairs. *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land.* Queen's Printer for Ontario; 1996.

Moseman, R. *Chemical disposition of boron in animals and humans.* Environ. Health Perspec. 1994; v 102 n 7 pp113-117.

Naylor, L.M. *Asbestos in Sludge - A Significant Risk?* BioCycle. 1989; v 30 n 1 pp51-53.

Neary, D.G., G. Schneider, and D.P. White. *Boron toxicity in red pine following municipal waste water irrigation.* Soil Sci. Soc. Am. Proc. 1975; v 39 pp981-982.

Oehme, F. *Toxicity of Heavy Metals in the Environment. Part 2*. Marcel Dekker, Inc. New York. 1979.

Omdahl, J., and H. de Luca. J. Biol. Chem. 1972; p247.

Page, A.L., T.G. Logan, J.A Ryan eds. L. Sommers, V. Van Volk, P.M. Giordano, W.E. Sopper, R. Bastian. *Effects of soil properties on accumulation of trace elements by crops*. Workshop on Effects of Sewage Sludge Quality and Soil Properties on Plant Uptake of Sludge – Applied Trace Constituents, Las Vegas. 1985; pp13-15.

Pahren H, W. Jakubowski eds. Wastewater Aerosols and Disease. Cincinnati, Ohio: US Environmental Protection Agency, EPA-800/9-80-028, 1980.

Parkpain, P., S. Sirisukhodom, and A.A. Carbonell-Barrachina. *Heavy Metals and Nutrients Chemistry in Sewage Sludge Amended Thai Soils*. Environ. Sci. Health, Pt. A: Toxic/Hazard. Subst. Environ. Eng. 1998; v A33 n 4 pp573-597.

Parkpain, P., S. Sreesai, and R.D. Delaune. *Bioavailability of heavy metals in sewage sludge-amended Thai soils*. Water, Air & Soil Pollution. 2000; v 122 n 1-2 pp163-182.

Patel-Mandlik, K.J., C.G. Manos, K.E.B. Johnson, V.L. Norton, and D.J. Lisk. Prevalence of Asbestos in Sludges from 16 Sewage Plants in Large American Cities in 1993. Chemosphere. 1994; v 29 n 6 pp1369(4).

Peterson, P.J., and C.A. Girling. "Other trace metals." In: N.W. Lepp (ed) *Effect of Heavy Metal Pollution on Plants. Vol 1. Effects of Trace Metals on Plant Function*. 279-342. Applied Science Publishers, New Jersey. 1981; pp213-278.

Pratt, P. Vanadium. In: *Diagnostic Criteria for Plants and Soils*. Chapman, H. (ed). Univ. of California, Div. Agric. Sci., Riverside. 1966; pp480-483.

Quin, B.F., and J.K. Syers. *Surface irrigation of pasture with Thailand sewage effluent*. New Zealand Journal of Agriculture Research. 1978; v 21 n 3 pp435-442.

Rappaport, B.D. *Availability and Distribution of Heavy Metals, Nitrogen, and Phosphorus from Sewage Sludge in the Plant-Soil-Water Continuum*. Virginia Polytechnic Institute and State University/Virginia Water Resources Research Center – Bulletin 154. 1987.

Romney, E. M., J. D. Childress, and G. V. Alexander. *Beryllium and the growth of bush beans*. Science 1962; v 185 pp786-87.

Sander, J., L. Dufour, R. Wyatt, P. Bush and R. Page. *Acute toxicity of boric acid and boron tissue residues after chronic exposure in broiler chickens*. Av. Dis. 1991; v 35 pp745-749.

Sisk, D., B. Colvin, A. Merllin, K. Bondari, and J. Bowen. *Experimental acute inorganic boron toxicosis in the goat: Effects on serum chemistry and CSF biogenic amines*. Vet. Hum. Toxicol. 1990; v 32 n 3 pp205-211.

Smith, G., and V. Anders. *Toxic effects of boron on mallard reproduction*. Environ. Toxicol. Chem. 1989; v 8 pp943-950.

Soon, Y.K., T.E. Bates, and J.R. Moyer. *Land application of chemically treated sewage sludge: Effects on plant and soil phosphorous, potassium, calcium and magnesium and soil pH*. J. Environ. Qual. 1978; v 7 n 2 pp269.

Sorensen, J.R.R., I.R. Campbell, L.B. Tepper, and R.D. Lingg. *Aluminum in the environment and human health*. Environm. Health. Persp. 1974; v 8 pp3-95.

Snyder, G.W., and C. Tsao. *Toxicological benchmarks for screening potential contaminants of concern for effects on aquatic biota: 1996 revision*. Oak Ridge National Laboratory. 1996.

Stone, E.L., and G. Baird. *Boron level and boron toxicity in red and white pine*. J. Forestry. 1956; v 54 pp11-12.

Substances and Processes Order of May 26, 1977. Statute Book 435. (based on subsections 1 and 3 of section 1, Chemical Waste Act, with the latest amendment of Mar. 17, 1988). Stature Book 145. The Hague, the Netherlands.

University of New Hampshire, Cooperative Extension. *Landspreading of Sludge in New Hampshire: Report of the UNH Sludge Task Force.* 1998. http://ceinfo.unh.edu/Agriculture/Documents/sludge.htm. (viewed January 2002).

Wallace, A. and E. M. Romney. Roots of higher plants as a barrier to translocation of some metals to shoots of plants. In: *Biological Implications of Metals in the Environment*. Proceeding of the Fifteenth Annual Hanford Life Sciences Symposium, Richland, WA. Tech Info Center, ERDA, Washington, DC. 1977; p370-379.

Wallace, A., G.V. Alexander, and F.M. Chaudhry. *Phytotoxicity and some interations fo the essential trace metals iron, manganese, molybdenum, zinc, copper, and boron*. Commum. Soil Sci. Plant Anal. 1977; v 8 n 9 pp741-50.

Wallace, A., and R.M. Romney. *Some interactions of Ca, Sr, and Ba in plants*. Agronomy J. 1971; v 63 pp245-248.

Water Environment Research Foundation (WERF). *Document Long-Term Experience of Biosolids Land Application Programs: Biosolids*. 1993.

Webber, M.D. *Assessment of Heavy Metals and PCB's at Selected Sludge Application Sites in Ontario – Research Report No. 109.* Environment Canada; Canada – Ontario Agreement on Great Lakes Water Quality. 1981.

Whitworth, M., G. Pendleton, D. Hoffman and M. Camardese. *Effects of dietary boron and arsenic on the behaviour of mallard duckings*. Envrion. Toxicol. Chem. 1991; v 10 pp911-916.

Will, M., and G.W. Suter II. *Toxicological benchmarks for potential contaminants of concern for effects on soil and litter invertebrates and heterotrophic processes*. Oak Ridge National Laboratory. 1995a.

Williams, R.J.B., and H.H. LeRiche. *The effect of traces of beryllium on the growth of kale, grass and mustard*. Plant soil. 1968; v 29 pp317-326.

Witkowska, D., R. Oledzka, and B. Markowska. *Effect of intoxication with vanadium compounds on copper metabolism in the rat*. Bull. Environ. Contam. Toxicol. 1988; v 40 pp309-316.

Zaporowska, H. and W. Wasilewski. *Significance of reduced food and water consumption in rats intoxicated with vanadium*. Comp. Biochem. Physiol. 1991; v 99C n 3 pp349-352.

Zitko, V. *Toxicity and pollution potential of thallium*. Sci. Tot. Environ. 1975; v 4 pp185-192.

Zitko, V., W. Carson, and W. Carson. *Thallium: Occurrence in the environment and toxicity to fish. Bull. Environ*. Contam. Toxicol. 1975; v 13 n 1 pp23-30.

4. Estrogenic Hormones and Pharmaceuticals

4.1 Background

The WEAO study, *Fate and Significant of Selected Contaminants in Sewage Biosolids Applied to Agricultural Land through Literature Review and Consultation with Stakeholder Groups*, (WEAO 2001) cited estrogenic hormones and pharmaceuticals as Group II contaminants.

Estrogenic hormones were considered as part of a larger group of endocrine-disrupting contaminants (agents that affect hormonal systems). These included a range of surfactant compounds (e.g. alkylphenol ethoxylates). However, these compounds were classified as Group I because of evidence that they do not persist in the environment. The study concluded that estrogenic hormones should be classified as Group II because of lack of data on their fate.

Estrogenic hormones also are a small subset of a broad range of pharmaceutically active compounds that often are lumped together with "personal care products" such as sunscreens and fragrances (PPCP – pharmaceuticals and personal care products). Estrogenic hormones are singled out as a specific concern because of their ability to act at very low dosages.

The presence of pharmaceutically active compounds in the environment was identified first in the 1970s. But it has only gained momentum as an area of concern in the 1990s with the identification of a range of pharmaceuticals and metabolites in sewage and natural water courses, including anti-inflammatory agents, betablockers, β_2-sypmpathomimetics, antiepileptics, antibiotics, X-ray contrast media, lipid regulators, contraceptives, and antineoplastics (Ternes 2001). Daughton (2001) cites improved chemical analysis methodologies and focussed research in Europe as reasons that this issue has come to the forefront.

Sources of these compounds include human sewage (only a portion of drugs administered are metabolized), animal wastes, industrial wastes (e.g. fish farms), hospital wastes, and improper disposal of medications.

4.1.1 Concerns

There is growing concern that pharmaceuticals may be having an effect on the natural environment. While few of these compounds are persistent, resisting degradation (Daughton 2001), the long-term effects of continuous low dosages in the environment are unknown. For example, Levitt et al. (2001) describe feminization of walleye downstream of a sewage treatment plant as consistent with exposure to estrogenic chemicals.

In addition, the presence of antibiotics in animal manure has been cited as a concern with respect to soil health. Concerns range from the effect on soil-nitrifying bacteria to demonstrated multiple drug resistance development in livestock microflora and pig intestines (Holling-Sorensen 1998).

Concerns regarding direct effect on humans usually are discussed in the context of contamination of drinking water. For example Clofibrate (a blood lipid regulator that is not readily biodegraded) was discovered in tap water and surface waters in Berlin, Germany (Holling-Sorensen 1998).

Little is known about the long-term public health risk of ingestion of drugs and drug metabolites at levels that are orders of magnitude below therapeutic doses. Richardson and Bowron (1985) calculated that the likely lifetime dose of non-biodegradable pharmaceuticals (over 70 years) would be equivalent to roughly one day's therapeutic dose. Richardson and Bowron (1985) also calculated that if oral contraceptives norethisterone and ethinyloestradiol were present in drinking water at their detection limits (10 ng/L and 5 ng/L, respectively), this would represent 1/17,500th and 1/2000th of prescribed daily doses.

Similarly, two risk assessments regarding pharmaceuticals cited in the European Commission report "Pollutants in Urban Waste Water and Sewage Sludge" (ICON 2001) concluded that there was negligible human risk, although further study was recommended.

Indirect effects on public health through the development of antibiotic-resistant organisms is a further area of needed study in the field.

4.2 Pharmaceuticals in Biosolids

While the fate of pharmaceuticals is an area of growing interest in the scientific and policy communities, there are two key questions with respect to pharmaceuticals and biosolids for the current investigation:

1. Is land application of biosolids a significant pathway for human exposure?
2. Are the concentrations experienced through this pathway significant?

The fate of pharmaceuticals is dependent on the physical/chemical characteristics of the specific compound. Unfortunately there is a deficit of information on the characteristics (e.g. biodegradability, octenol/water partition coefficient, etc.) of specific compounds, although the fate of some broad classes of compounds can be hypothesized.

The European Commission study (ICON 2001) reported that more than 30 percent of drugs produced between 1992 and 1995 are lipophillic in nature and therefore will tend to accumulate in the biosolids during sewage treatment. Polar antibiotics, for example, fall into this category. Pharmaceuticals generally become more water-soluble when they are metabolized (Holling-Sorensen 1998) so the metabolites are less likely to end up in the biosolids. If the metabolites do enter the environment, however, they tend to be cleaved and transformed to back to their parent compounds (ICON 2001). For example, drug metabolites in liquid manure from medicated livestock were found to revert to the parent drug by bacterial action (Holling-Sorensen 1998). Some of the compounds, although lipophillic in nature, are biodegradable either in the treatment plant itself or in the soil.

Estrogenic hormones are hydrophobic (lipophillic) in nature and will tend to adsorb to solids including soil (Larsen 2001). While sources cited by Holling-Sorensen et al. (1998) suggest that estrogen is persistent in both sewage and soils, further work by Colucci (2001a,b), specifically in the context of manure and biosolids management, found removal of both natural (17β estradiol and estrone) and synthetic (17β ethynynlestradiol) forms of estrogen under a range of soil temperature and moisture conditions.

Estrogenic hormones are of concern because of their potential for effect at very low concentrations (e.g. effects on fish as low as 1 ng/L (Colucci 2001a). However, from this information, initial indications are that biosolids do not represent a significant pathway for estrogenic hormones to affect human health (Topp 2002).

Whether specific drugs would be lipophillic (i.e. retained with the biosolids), resistant to degradation, and accumulate in sufficient concentration to cause an effect in the food chain (i.e. persistent, toxic, and bioaccumulative) is still a matter for debate and research. Compounds with higher octanol-water partition coefficients (more lipophillic) generally are considered to represent a risk of bioaccumulation. There are exceptions, such as the work by Migliore et al. (1996) that demonstrated bioaccumulation of a sulphamide, which is in animal feed additives and appears in manure, in barley. The European Commission report (ICON 2001) cites an effort by Duarte and Davidson using octanol-water partion coefficients (a measure of lipophilicity) and Henry's Law constants (volatility) to prioritize pollutants for assessment.

4.3 Ongoing Research and Policy Development

The fate of pharmaceuticals and other personal care products in the environment is an emerging area of study and policy development. Effects on the natural environment, as well as potential effects on humans through long-term, low-dose exposure; synergistic drug effects; and antibiotic resistance are continued areas of concern and study.

Some authors (ICON 2001, Daughton 2001, Holling-Sorensen 1998) recommend that new pharmaceuticals (as well as existing ones) be evaluated for environmental fate/effect as part of the drug approval policy. Differences between regulation of pharmaceuticals for human and pharmaceuticals for veterinary or agricultural application add to the complication.

The USEPA maintains a useful website on pharmaceuticals and personal care products in the environment that tracks the growing body of work in this area: http://www.epa.gov/esd/chemistry/ppcp/reference.htm.

4.4 References

Colucci, Michael S., and Edward Topp. *Persistence of Estrogenic Hormones in Agricultural Soils I: 17β Estradiol and Estrone*. J. Environ. Qual. 2001; 30 pp. 2070-2076.

Colucci, Michael S., and Edward Topp. "Persistence of Estrogenic Hormones in Agricultural Soils II: 17β Ethynylestradiol " J. Environ. Qual. 2001; 30 pp. 2077-2080.

Daughton, Christian G. *Pharmaceuticals and Personal Care Products in the Environment: Overarching Issues and Overview*. Presented in Symposium Series 791. American Chemical Society, Washington D.C.; 2001.

Holling-Sorensen, B., S. Nora Nielsen, P.F. Lamzky, F. Ingerslev, H.C. Holten Lutzhaft, and S.E. Jergensen. *Occurrence, Fate and Effects of Pharmaceutical Substances in the Environment – A Review*. Chemosphere. 1989; Vol. 36, No. 2, pp. 357-393.

ICON, I C Consultants. *Pollutants in Urban Waste Water and Sewage Sludge*. Prepared by ICON, IC Consultants for the European Commission Directorate – General Environment. http://europa.eu.int; 2001.

Larsen, G., F. Casey, B. Magelky, C. Pfaff, and H. Hakk. *Sorption, Mobility and Fate of 17β-Estradiol and Testosterone in Loam Soil and Sand*. Proceedings of the 2nd International Conference on Pharmaceuticals and Endocrine Disrupting Chemicals in Water. National Ground Water Association, October 2001, Minneapolis, Minnesota.

Levitt, James T., Heiko L. Schoenfuss, and Ira R. Adelman. *Possible Effects of Endocrine Disrupting Compounds on Walley, Stizostedion vitreum, Near the Metro Sewage Treatment Plant, Saint Paul, Minnesota.* Proceedings of the 2nd International Conference on Pharmaceuticals and Endocrine Disrupting Chemicals in Water, National Ground Water Association, October 2001, Minneapolis, Minnesota.

Migliore, Luciana, Gianfranco Brambilla, Paolo Casoria, Cinzia Civitareale, Salvatore Cozzolino, Luciano Gaudio. *Effect of sulphadimethoxine contamination on barley (Hordeum distichum L., Poaceae, Liliopsida.* Agriculture, Ecosystems & Environment. 1996; vol. 60, pp 121-128.

Richardson, Mervyn L., and Judith M. Bowron. *Review: The fate of pharmaceutical chemicals in the aquatic environment*. J. Pharmacy and Pharmacology. 1985; vol. 37, pp 1-12.

Ternes, Thomas. *Pharmaceuticals as New Emerging Environmental Contaminants: A Survey*. Proceedings of the 2nd International Conference on Pharmaceuticals and Endocrine Disrupting Chemicals in Water, National Ground Water Association, October 2001, Minneapolis, Minnesota.

Topp, Edward. Personal interview. 7 February 2002.

5. Emerging Issues

5.1 Background

In addition to the issues identified in the WEAO report, which served as the starting point for this project, other emerging issues that have the potential to affect biosolids land application were identified. The two emerging issues discussed in this section were identified from recently published work, *Potential health effects of odour from animal operations, wastewater treatment and recycling of byproducts* (Schiffman et al 2000) in the case of odour and *Persistent pollutants in land-applied sludges* (Hale et al, 2001) in the case Polybrominated diphenyl ethers (PBDEs, or flame-retardants). The issue of PBDEs also was followed-up through an interview with Dr. Hale.

5.2 Odour and Potential Health Effects

Biosolids are a rich organic mixture that can emit a variety of volatile organic compounds either alone (e.g. amines, ammonia, mercaptans) or bound to fine particles (e.g. organic dusts). Over the last several decades, research on the measurement of odours and physiological and clinical reactions to odours has been conducted in a wide variety of fields. Unfortunately, no research reports were available that identified odour-related health effects associated with biosolids field application.

A recent workshop attempted to bring together the disparate research to focus on general population exposures to odour from animal operations, wastewater treatment, and their by-products, though not biosolids per se. The workshop resulted in a review article by Schiffman et al. (2000). They outlined a range of reactions to odour, from detection and recognition through annoyance, intolerance , and irritation, to toxicity.

Annoyance at environmental exposures has long been recognized (Koelegal 1987). Perceptions of odour-annoyance vary by type of odour (Cole 1999), distance from local sources (Winneke and Kastka 1987), and levels of health concern (Elliott 1993). Some populations, such as those with multiple chemical sensitivities, may be particularly prone to such effects.

Irritation predominantly involves the eyes and respiratory tract. The majority of clinical and laboratory tests available to document odour-related health effects are used for irritant/ inflammatory/immune effects, often associated with known pollutants such as organic dusts and endotoxin/lipopolysacharides (LPS). Such effects may cause, for example, an exacerbation of existing respiratory disease in high concentration facilities, such as swine confinement buildings. They also are more clearly proportional to measurable levels of exposure, such as decreasing pulmonary function with LPS challenges. Although some of the health effects outlined in the case series discussed in Section 6 may be operating through these mechanisms, the direct relevance of indoor high exposure situations (e.g. confined buildings) to the lower exposure situations of outdoor biosolids application are less clear.

Whole body stress effects, including psychological distress and central nervous system dysfunction, also have been reported. As part of the larger literature on psychosocial impacts of proximity to waste (Eyles 1993), such health effects are consistent with a general understanding of health concern-health effects relationships. Risk perception literature suggests that environmental odour experiences/annoyance may mediate reporting of a wide range of health effects on this basis alone.

The relationship between odour experiences and health effects is on-going.

5.2.1 References

Cole, D.C., L.D. Pengelly, J. Eyles, D.M. Stieb, R. Hustler. *Consulting the community for environmental health indicator development: the case of air quality*. Health Promotion International. 1999;14(2):145-154.

Dowd, S.E., C.P. Gerba, I.L. Pepper and S.D. Pillai. *Bioaerosol Transport Modeling and Risk Assessment in Relation to Biosolids Placement*. J. Environ. Qual. 2000; 29 pp343-348.

Elliot S.J., S.M. Taylor, S. Walter, D. Steib, J. Frank, J. Eyles. *Modelling psychosocial effects of exposure to solid waste facilities*. Social Science and Medicine. 1993; 37(6): 791-805.

Eyles J., S.M. Taylor, N. Johnson, J. Baxter. *Worrying about waste: living close to solid waste disposal facilities in Southern Ontario*. Social Science and Medicine. 1993; 37(6): 805-812.

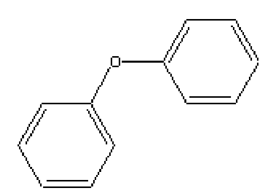
Koelega H.S. (ed.). *Environmental Annoyance: characterization, measurement and control*. Amsterdam et al: Elsevier Science Publishers; 1987.

Schiffman S.S., J.M. Walker, P. Dalton, L.S. Lorig, J.H. Raymer, D. Shusterman, S.M. Williams. *Potential health effects of odour from animal operations, wastewater treatment and recycling of byproducts*. Journal of Agromedicine. 2000; 7(1): 7-81.

Winneke, G., J. Kastka,. *Comparison of odour-annoyance data from different industrial sources: problems and implications*. Koelega, H.S. ed. Environmental Annoyance: Characterization, Measurement and Control. Amsterdam et al.: Elsevier, 1987: pp129-138.

5.3 Polybrominated Diphenyl Ethers (PBDEs)

Polybrominated diphenyl ethers are a group of persistent and bioaccumulative compounds used as flame-retardants. Widely used in furniture foams, textiles, and plastic housings for electronics (Hale 2001), they have recently gained notoriety with their discovery at relatively high levels in fish tissue, biosolids, and human breast milk. Minimal information is available on the long-term toxicological effects of PDBEs, but their structure suggests they have a potential to affect endocrine (hormonal) and hepatic systems as well as cause potential neurodevelopmental effects (Hale 2001).



diphenyl ether structure

Concentrations in fish of the total tetra- to hexabrominated congeners ranged from <5 to 47,900 ug/kg (lipid basis) (Hale 2001). Levels in human breast milk in North America are 40 times higher than measurements in Sweden, ranging as high as 200 ug/kg (Betts 2001). Levels measured in biosolids in North America ranged from 1,100 to 2,290 ug/kg (dry weight) of the major commercial formulation (so-called "Penta") and are 10- to 100-fold higher than measurements in European biosolids (Hale 2001b).

Based on a recent personal interview with Dr. Hale and on the strongly lipophilic nature of these compounds[3], there is no clear mechanism of transport from land-applied biosolids to humans, but Dr. Hale remains concerned that biosolids may represent a mechanism for PBDEs to enter into the general ecosystem through benthic organisms and wildlife.

Dr. Hale's research also has shown increasing global consumption of PBDEs and that the "most bio-accumulative and toxic BDEs are being detected in humans and wildlife from both developed and remote areas" (Hale 2001).

The European Commission has recently proposed a ban on the use of the Penta formulation PBDEs, based on concerns about the levels in human breast milk (Hale 2001b). In North America, however, the push for improved fire protection standards may promote increased use of these fire retardants (Hale 2002).

5.5 References

Betts, Kellyn S. *Rapidly rising PBDE levels in North America.* Science News. http://pubs.ac.org/subscribe/journals/esthag-w/2001/dec/science/kb_pbde.html; 7 December 2001.

Hale, Robert C., Mark J. La Guardia, Ellen Harvey, T. Matt Mainor, William H. Duff, Micheal O. Gaylor. *Polybrominated Diphenyl Ether Flame Retardants in Virginia Freshwater Fishes.* Environmental Science and Technology. 2001; Vol. 35, no.23: pp4585-4591.

Hale, Robert C., Mark J. La Guardia, Ellen Harvey, T. Matt Mainor. *Potential role of fire retardant-treated polyurethane foam as a source of brominated diphenyl ethers to the U.S. environment*. Scheduled for publication in Chemosphere in 2002.

Hale, Robert C., Mark J. La Guardia, Ellen Harvey, T. Matt Mainor, Micheal O. Gaylor. *Persistent pollutants in land-applied sludges*. Nature. 12 July 2001; Vol 412, pp140-141. (Hale b)

Hale, Robert C. Personal Interview. 30 January, 2002.

[3] The log of the octanol-water partition coefficient (K_{ow}) is approximately 6 for PBDEs with between 4 and 8 bromines.

6. Health Studies

6.1 Background

Determining the potential human health effects (if any) of exposure to biosolids is a challenge, as in many other areas of environmental epidemiology (Cole 1999). Following are key components for determining likely causal associations:

1. An adequate characterization of the source of potential exposures
2. Documentation of pathways of potential exposure under particular sets of conditions
3. Likely health outcomes associated with exposure to the different constituents
4. Documentation of other factors or exposures that could confound association(s) between exposure(s) and health outcome(s) of interest (Lillienfield and Stolley 1994, Rothman & Greenland 1998)

Unfortunately, experts on these components usually are different: engineers, microbiologists, or chemists to characterize the source; agronomists, hygienists, or exposure assessors to document pathways; occupational and environmental health specialists to determine likely health outcomes; and clinicians and epidemiologists to document confounding exposures.

The result is that none of the papers reviewed addressed all components, given that the constituents of different forms of biosolids may vary substantially, as do methods of application (and hence exposures) and health outcomes of relevance (e.g. infection versus irritation). In general, few studies gave consideration to exposures other than biosolids that might confound the biosolids-health effects relationship. Further, the group of relevant studies on exposure to biosolids included both heterogenous populations (sewage treatment plant workers, neighbouring residents, hauling and spreading contractors, farm families, and residents around land application sites) and heterogeneous study designs.

Table 6-1 sets out two broad means of determining potential burdens of illness related to biosolids — risk estimation and measurement of associations in humans. Within each column, a typology of components is provided and, when appropriate, examples of studies that exemplify each approach are given.

An example of a study that deals with specific component hazards, whose impact is more likely to be assessed through risk assessment methods, is Dowd et al. (2000), which is described in the pathogens section of this report. Several of the human observational studies are interesting but are not directly applicable to land application of biosolids. For example Vonstille et al. (1993) studied residents with exposure to raw sewage, which is like studies from developing countries on untreated wastewater exposure in farm worker populations, and so are not commented further upon here.

Case reports and case series that help define the nature of the health problems that may be associated with exposures are an important first step. Unfortunately, with respect to resident exposure to biosolids land application, there are too few good case reports available. Such a lack could occur for a number of reasons:

- Few health problems have been noticed by residents
- Few required clinical care
- Few clinicians associated the health problems with biosolids
- Few clinicians took the time to voluntarily report or write up the case(s)

While there commonly are requirements to report and investigate a variety of reportable conditions such as hepatitis or food poisoning using established protocols, a similar surveillance system for monitoring health effects from biosolids does not appear to exist in any jurisdiction. While anecdotal cases are occasionally reported by the news media, few of these are investigated by trained teams of agronomists, engineers, toxicologists, microbiologists, or public health professionals, let alone make their way into the peer-reviewed research literature.

Epidemiological studies with comparison populations (cross-sectional, case-control, and cohort) are generally thought to be more conclusive than case reports and case series, provided that other elements such as source characterization, exposure assessment, health outcome assessment, and confounder assessment are comparable (Lillienfield 1994). Studies using these more rigorous designs, either of workers (generally higher exposed) or of residents with a range of exposure are outlined in Table 6-2a. These studies provide the best human health evidence available about potential health effects associated with complex exposures. Yet these exposures may differ substantially from those experienced by application workers and residents during land applications of particular kinds of biosolids.

6.2 Worker Studies

The US National Institute for Occupational Safety and Health has conducted one assessment at a biosolids storage site and land application operation (NIOSH 1999). Air samples detected enteric bacteria and five workers interviewed reported at least one episode of gastrointestinal illness after working with biosolids either at the treatment plant or during land application.

A number of case reports on illness among sewage treatment plant (STP) workers are available. For example Brautbar and Navizadeh (1999) focused on two STP workers who contracted Hepatitis C, concluding that it was most likely caused by exposure to contaminated sewage water. Sekla (1980) studied a group of STP workers in Winnipeg and found the most common health complaints were respiratory problems. On screening stool tests, they isolated a protozoal parasite, *Giardia lamblia*, in three operators but did not find pathogen exposure-illness relationships across different levels of likely wastewater exposure. Nethercott (1981) described an outbreak of contact dermatitis (inflammation of the skin) among Toronto STP workers exposed to sewage sludge which resolved upon improved maintenance and cleanup of the operation. Nethercott and Holness (1988) later described an “influenza-like” respiratory syndrome among STP workers, with acute illnesses in the sludge-drying area.

A number of cross-sectional studies also have been carried out on STP worker populations, as summarized by Clark (1986a & b) (see also Table 6.2a for descriptions). Khuder et al.

(1998) reported that STP workers reported a significantly higher prevalence of gastrointestinal and gastroenteritis symptoms as well as headaches. Lundholm and Rylander (1983) conducted more detailed exposure assessments and concluded that the STP workers had specific work related symptoms that were from acute effects from exposure to endotoxins, which could explain some of Nethercott and Holness' respiratory syndrome.

Among the cohort studies that Clark and Linnemann (1986b) summarized, Clark et al. (1980) reported an increased level of minor gastrointestinal illness among inexperienced STP workers compared with experienced workers and unexposed controls, but no increases in viral seroconversions among the inexperienced workers over a three year period. Retrospective cohort studies have examined mortality among groups of STP workers put together through employment and other records and linked with sources of data on cause of death. For example, Lafleur and Vena (1990) found elevated death rates for cancer among a small cohort of sewage workers, especially STP operators, compared with age- and gender-specific death rates in the general population. They attributed these non-significant elevations to chemical exposures that were substantial (e.g. Lurker et al. 1983) prior to more recent programs of source reduction by environmental ministries and municipal utilities.

6.3 Resident Studies

In a 1998 case report, Singer studied neuropsychological symptoms in a family exposed to sewage sludge in Washington State and concluded that they exhibited symptoms consistent with exposure to sewage sludge. However, exposure assessment was fundamentally by self-report and later observation, rather than by independent hygiene measurements, and potential confounders were not clearly described.

In a case series, obtained through unclear selection criteria, Lewis et al. (internal review only) studied 49 residents living near and downwind from nine USEPA Class B biosolids land application sites. Exposure and health outcome information was obtained via questionnaires, with some site visits in the US with complementary researcher observation and exposure modeling. US residents were near one of eight sites in the United States that apparently all received multiple applications of lime-stabilized sludge over several years (Lewis 2002). Several *staphylococci* infections were reported, some severe.

The Canadian resident was near the ninth site in Ontario, which had received a single application of anaerobically digested de-watered biosolids from the city of Toronto. S/he reported symptoms of short duration (eight hours). Lewis concluded that exposure to the combined effects of airborne lime and *staphylococcus* on dust particles might account for the symptoms.

Cement kiln dust, commonly used to adjust the pH in lime-stabilized biosolids, can itself result in acute and chronic symptoms, including bronchial irritation, headache, dizziness, chronic dermatitis, and conjunctivitis following exposure through inhalation, skin contact, and eye contact (Ash Grove Cement Company Material Safety Data Sheet).

It should be noted that the City of Ottawa does not add lime to the de-watered cake produced for land application.

Cohort studies have involved residents close to wastewater treatment plants (Johnson et al. 1980, Northrop et al. 1980), near a wastewater land application site (Caman et al. 1985) and near a sewage sludge land application (Dorn et al. 1985, Ottolenghi and Hamparian 1987) (see Table 6-1.) The first three studies did not used external referents but examined proximity or exposure index associations with markers of new infections over the period of study. In general, though some associations between exposure and viral sero-conversion were found, such associations were inconsistent among the many comparisons made, sometimes confounded with other exposures and often of small magnitude.

The land-applied municipal sewage sludge cohort included 164 people in 78 families on farms where municipal sewage sludge was applied and 130 people in 53 families on referent farms (Dorn et al, 1985).

Over a three-year period, the researchers collected serological data as well as clinical histories, including general symptoms, respiratory illnesses, and digestive illnesses. Rates of illness among the exposed and reference populations were similar. Relatively small areas of land received applications on the exposed farms and details on the location of the spread fields in relation to the farm residences, or on the timing and means of application were lacking (Clark 1986).

In the same cohort, Ottolenghi and Hamparian focused on exposure to *Salmonella* and *Shigella* (1987). They collected municipal sewage sludge samples from four waterwater treatment plants in the study area. Of the 21 serotypes of *Salmonella* isolated from the sewage sludge , *Salmonella infantis* was the most common. They also collected blood and stool samples from the studied individuals. The authors reported that the risk of infection among the sewage sludge exposed population was not different from that of the reference population. Although authors of these studies caution against extrapolating their results to other situations with different type of sewage sludge or application practices, they appear to be the closest to current Ottawa applications available.

TABLE 6-1
Methods of Assessing Potential Health Effects Associated with Biosolids Exposures

Estimation via Risk Assessment	Inference from Observations in People
Studies on Animals Evidence of toxicity via toxicological studies in animals or pathogenicity via microbiological studies in animals, usually with estimation of dose-response relationships.	**Studies of Human Cases** Case reports on individuals or families (e.g. Singer 1999 for biosolids on land) or case series bringing together a number of case reports (e.g. Lewis et al., under review, for biosolids on land; Nethercott, 1981 for sewage workers), but with denominator usually unclear.
Exposure in Humans Either measured or estimated in some fashion via an understanding of any transformations that may occur in the components of biosolids.	**Surveillance of Populations** Cases reported to public health authorities with delineation of space and time clustering of cases in defined populations (e.g. Vonstille et al. 1993 for raw sewage; none for biosolids).
Burden of Health Effects in Humans Based on distributions of exposure, dose-response relationships and safety factors, likely burdens of health effects can be estimated (e.g. Dowd et al. 2000). Synergistic or antagonistic effects hard to predict.	**Cross-Sectional Surveys** Comparisons of health outcomes in groups of people during a relatively brief time period (e.g. Lundholm & Rylander 1983 for sewage workers). However, often subject to important selection biases.
	Case-Control Studies If have good definition of clinical syndrome likely to be present in cases, can compare past exposure of cases and non-cases (none found).
	Cohort Studies Follow groups of people with different degrees of exposure forward in time and see if illness occurrence differs (e.g. Dorn et al., 1985 for farm families).
	Intervention Studies Reductions in exposure lead to reductions in symptoms or illness among exposed groups (e.g. Nethercott, 1981 for dermatitis in sewage workers), though pre-post is weak design.

TABLE 6-2A
Epidemiological Studies with Comparison Groups of Potential Relevance to Assessment of Biosolids Health Effects
A: Sewage Treatment Plant (STP) Workers

Authors (year)	Design	Exposed Population(s)	Reference Population	Exposure Assessment	Health Outcome Information Collected	Results
Clark, et al. (1980)	Cohort	STP workers >100 new workers for activated sludge plant, 50 sewer maintenance workers and 50 longstanding primary STP workers, family members of STP workers	Highway maintenance workers	Occupational exposure to wastewater and to viable wastewater treatment plant aerosols By group plus environ-mental monitoring in the plant	Viral and bacterial sero-survey Evaluation of immune status Isolation and identification of pathogens Clinical illness monitoring Yearly health examinations	Unable to demonstrate increased risk of infection in exposed workers. No consistent evidence of increased parasitic, bacterial or viral infections as indicated by stool examinations, cultures and antibody surveys. Observed an increased level of minor gastrointestinal illness in inexperienced sewage exposed workers compared to experienced exposed workers and controls.
Khuder, et al. (1998)	Cross-sectional	STP workers	College maintenance & oil refinery workers	Group only	Infectious diseases and associated symptoms on questionnaire	TP workers reported significantly higher prevalence of gastroenteritis, gastrointestinal symptoms and headaches. No significant difference found with regard to respiratory or other symptoms.
Lafleur & Vena (1990)	Retro-spective Cohort	487 White Male STP workers	General Population	Employment records	Cause of death on death certificates	Increased risk of cancer among exposed sewage workers, especially operators but not significant in small cohort. Industrial chemical exposures in wastewater implicated.
Lundholm & Ry-lander (1983)	Cross-sectional	STP workers	Water treatment plant workers	Airborne pathogens via environmental monitoring	Serum immunoglobulin concentrations, white blood cell counts, fibrinogen degradation product, number and species of airborne gram neg. bacteria, clinical symptoms	The data suggest that workers in STPs have specific work related symptoms that are due to acute effects of toxins from gram negative bacteria in the environment A significantly higher proportion of sewage workers reported work related gastrointestinal symptoms No significant difference was noted between exposed and control group from which blood cell count or serum immunoglobulin concentrations.
Trout, et al. (2000)	Cross-sectional survey	STP workers	Other city employees	Practices and environment on questionnaire	Hepatitis A sero-markers and saliva samples to test for anti-HAV	Prevalence of HAV higher among exposed but not significantly so in relatively small sample.

TABLE 6-2B
Epidemiological Studies with Comparison Groups of Potential Relevance to Assessment of Biosolids Health Effects
B: Farm and Resident Populations (all prospective cohort studies)

Authors (year)	Exposed Population(s)	Reference Population	Exposure Assessment	Health Outcome Information Collected	Results
Caman et al. (1985)	478 residents and farm workers	None	Prior to and after land treatment & bioaerosol dispersion modeling	Illness episodes & multiple viral sero-conversions & stool samples	Good consideration of confounding exposures via air conditioner in local restaurant and local wells. Mixed relationships: slightly higher rates of viral infections among members of population with higher aerosol exposure but weak associations between exposures and specific viral infections. No evidence of parasitic infections associated with wastewater exposure.
Dorn et al. (1985)	Farm families 164 people in 78 families	130 people in 53 families distant from land application sites	See Ottolenghi & Hamparian	Tuberculin testing, serum naturalization testing, clinical history	Based upon examination of descriptive data and statistical analysis, the rate of illness in the exposed population was not higher than that of the control population. Illnesses considered include respiratory, digestive and general symptoms. Caution should be used in using the data to predict health risks associated with sludges containing higher levels of disease agents and with higher application rates and larger treated acreages per farm than in the present study.
Ottolenghi & Hamparian (1987)			Sludge samples	Stool samples and serology for Salmonella shigella	21 different serotypes of *Salmonella* were isolated from the sewage sludge. The most common was *Salmonella infantis*. The risk of infection of the population exposed to such salmonellae was judged to be minimal and no different from the non exposed population
Johnson et al., (1980)	226 residents living around new STP	None	Distance from plant - 0.35 to 5 km. Pre and post plant opening	Sero-conversions for enteroviruses	No correlation between distance from plant and seroconversions. Concluded that treatment plant opening not associated with viral infection.
Northrop et al., 1980	318 residents within 1.6 km of activate sludge STP	None	Household exposure index & total airborne viable particle concentrations	Sero-conversions for coxsackie, echo-, and polio-viruses	Mixed pattern of associations: positive for four-fold titre increases for coxsackie and exposure index but opposite direction for echoviruses. None statistically significant.

6.4 References

Brautbar, N., N. Navizadeh. Brief Communication: Sewer Workers: Occupational Risk for Hepatitis C - Report of Two Cases and Review of Literature. Archives of Environmental Health. 1999; Vol. 54 No. 5.

Camann, D.E., P.J. Graham , M.N. Guentzel, H.J. Hardin, K.T. Kimball, B.E. Moore, R.L. Northrop, N.L. Alman, R.B. Harris, A.H. Holguin, R.L. Mason, C.B. Popescu, C.A. Sorber. Health Effects Study of the Lubbock Land Treatment Project. Research Triangle Park, N.C. USA: US Environmental Protection Agency, EPA-600/1-85-023, 1985.

Clark, C.S., G.L. Van Meer, C.C. Linnemann, A.B. Bjornson, P.S. Gartside, G.M. Schiff, S.E. Trimble, D. Alexander, E.J. Cleary; J.P. Phair. Health Effects of Occupational Exposure to Wastewater. Pahren H, W. Jakubowski eds. Wastewater Aerosols and Disease. Cincinnati, Ohio: US Environmental Protection Agency, EPA-800/9-80-028, 1980; pp239-264.

Clark, C.S. Health effects associated with wastewater treatment and disposal. Journal WPCF. 1986; (a); 58(6) pp 539-543.

Clark, C.S., C.C. Linnemann. The use of serum antibody as a means to determine infections from exposure to wastewaters and refuse. CRC Reviews in Environmental Control. 1986(b); 16(4) pp 305-326.

Cole, D.C., R. Upshur , B.L. Gibson. Environmental burden of human illness: scoping the problem. Alternatives. Summer 1999;25(3) pp26-32.

Dorn, R.C., C.S. Reddy, D.N. Lamphere, J.V. Gaeuman, R. Lanese. Municipal Sewage Sludge Application on Ohio Farms: Health Effects. Environmental Research. 1985; 38 pp332- 359.

Dowd, S.E., C.P. Gerba, I.L. Pepper, S.D. Pillai. Bioaerosol transport modelling and risk assessment in relation to biosolid placement. J Environ Qual. 2000; 29 pp343-348.

Johnson D.E., D.E. Camann, K.T. Kimball, R.J. Prevost, R.E. Thomas. Health effects from wastewater aerosols at a new activated sludge plant. Pahren H, W. Jakubowski eds. Wastewater Aerosols and Disease. Cincinnati, Ohio: US Environmental Protection Agency, EPA-800/9-80-028, 1980; pp136.

Khuder, S.A., T. Arthur, M.S. Bisesi, E.A. Schaub. Prevalence of Infectious Diseases and Associated Symptoms in Wastewater Treatment Workers. American Journal of Industrial Medicine. 1998; 33 pp571-577.

Lafleur, J., J.E. Vena. Retrospective Cohort Mortality Study of Cancer Among Sewage Plant Workers. American Journal of Industrial Medicine. 1991; 19 pp75-86.

Lewis, D.L., D.G. Gattie, M. Novak, S. Sanchez, C. Pumphrey. Interactions of pathogens and irritant chemicals in land-applied sewage sludge (biosolids). (internal EPA review so far). 2002.

Lewis, D.L. personal interview. 19 February 2002.

Lilienfield, D.E., P.D. Stolley. Foundations of Epidemiology. 3rd Ed. Oxford University Press, 1994.

Lundholm, M., R. Rylander. Work related symptoms among sewage workers. British Journal of Industrial Medicine. 1983; 40: pp325-329.

Lurker, P.A., C.S. Clark, V.J. Elia, P.S. Gartside, R.N. Kinan. Worker exposure to chlorinated organic compounds from the activated-sludge wastewater treatment process. Am Ind Hyg Assoc J. 1983; 44(2) pp109-112.

Nethercott, J. Airborne irritant contact dermatitis due to sewage sludge. J Occup Med. 1981; 23 (11) pp771-774.

Nethercott, J., D.L. Holness. Health status of a group of sewage treatment workers in Toronto, Canada. Am Ind Hyg Assoc J. 1988; 49(7) pp346-350.

Northrop, R.L., B. Carnow, R. Wadden, S. Rosenberg, A. Neal, L. Sheaff, J. Holden, S. Meyer, P. Scheff . Health effects of aerosols emitted from an activated sewage sludge plant. Pahren H, W. Jakubowski W eds. Wastewater Aerosols and Disease. Cincinnati, Ohio: US Environmental Protection Agency, EPA-800/9-80-028, 1980: pp180.

NIOSH. Hazard evaluation and technical assistance report: Biosolids Land Application Process, LeSourdville, OH. Cincinnati, OH, USA. US Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 98-0118-2748.

Ottolenghi, A.C., V.V. Hamparian. Multiyear Study of Sludge Application to Farmland: Prevalence of Bacterial Enteric Pathogens and Antibody Status of Farm Families. Applied and Environmental Microbiology. 1987; Vol. 53 pp1118-1124.

Rothman, K.J., S. Greenland. Modern Epidemiology. Philadelphia et al: Lippincott Williams & Wilkins, 1998.

Sekla, L., D. Gemmill, J. Manfreda, M. Lysyk, W. Stakiw, C. Kay, C. Hopper, L. Van Bukenbout, G. Eibisch. Sewage treatment plant workers and their environment: a health study. Pahren H, W. Jakubowski eds. Wastewater Aerosols and Disease. Cincinnati, Ohio: US Environmental Protection Agency, EPA-800/9-80-028, 1980: pp281-294.

Singer, R. Neurotoxicity from Municipal Sewage Sludge. Archives of Clinical Neuropsychology. 1999; 14(1) pp160.

Singer, R. personal interview. 20 February 2002.

Vonstille, W.T., R.C. Sharer. Hepatitis A epidemics from utility sewage in Ocoee, Florida. Arch Environ Health. 1993; 48 (2) pp120-124

7. Interim Best Management Practices

Interim best management practices (BMPs) were developed based on the review of the literature, information gathered from the interviews, and experience in the field. The interim BMPs are a series of procedures designed to manage the biosolids program in a manner that is consistent, transparent, and verifiable, and in excess of the Ontario Ministry of Environment guidelines. The interim best management practices are divided into seven program elements:

1. Site Selection and Approval
2. Land Application
3. Inspection and Monitoring
4. Source Controls
5. Communication
6. Incident Response
7. Training

Each program element relates to a series of items that will have associated best management practices along with a rationale or basis for each interim BMP.

The premise behind the interim BMPs is that limiting public contact with biosolids may mitigate potential public health risks from exposure. They also address some of the concerns raised during public consultation for the Biosolids Management Plan Update. The interim BMPs cover all aspects of the land application program, from selecting application sites, the approval process, and spreading activities, to recordkeeping and auditing. Emergency measures and at-source controls also are addressed. The driver for each of the BMPs is noted in Table 7-1: <u>Health Protection</u>, program <u>Transparency</u> to the public, and <u>Conservative Approach</u> which standardizes methodologies and separation distances.

It is expected that final best management practices for the City of Ottawa will result from the following three Provincial initiatives currently underway:

1. Review of the *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land.*

2. Development and implementation of the Nutrient Management Act and related regulations

3. Development and demonstration of an environmental management system for biosolids management; the City of Ottawa is one of three pilot cities for this project, which is receiving some funding from the MOE and Environment Canada

TABLE 7-1
Interim Best Management Practices for the City of Ottawa
Site Selection and Approval, Spreading, Inspection and Monitoring, Source Controls, Communications, Incident Response, Training

Program Element	Item	MOE Guideline	BMP	Basis / Rationale	Current Practice	Health Protection	Transparency	Conservative Approach
Site Selection Pre-Screening	Overview			Avoid investment by contractor to license sites in compliant with the Guidelines but not the Best Management Practices Documentation of informed consent by the city				
	Separation Distance to Population Centre	Section 6.14 of the Guidelines indicates: 50 – 450 meters from a residential area. Residential area is not defined in the Guidelines 25 – 90 meters from an individual residence	Sites under consideration are a minimum of 450m from any population centres. Population Centre defined as: • Residential area as defined by the Guide to Applying for a Certificate of Approval to Spread Sewage and Other Biosolids on Agricultural Land (Section M, March 1996), • A school, • a multiunit residence such as an apartment or retirement home, • an employment area, employment cluster or employment centre as defined by the Region of Ottawa Carleton Official Plan. • Sites under consideration are a minimum of 90m from any individual residence	Section 6.14 of the Guidelines requires a minimum normal separation distance of 450m. While not defined as a residential area, multi-unit buildings are similar to residential areas. The Guidelines provide for a reduction of the separation distance to 50m where the material is incorporated within 24 hours, however, odour concerns preclude this from being a good management practice. Citizens in Ottawa have expressed concerns that the Guidelines referring to residential areas are not sufficiently comprehensive. This BMP is in response to this community's concern.	90m from residence. 450m from population centre only as defined by Guidelines (doesn't include schools).			✔
	Land Use Restrictions	Table 7 of the Guidelines outlines spreading restrictions related to public health. The waiting period for all vegetable crops is 1 year.	Farmer is willing to agree to crop restrictions following biosolids application as follows: Vegetable crops (non-root) 1 year Vegetable crops (root) 5 years Vegetable crops are grown for direct (unprocessed) human consumption. Vegetable crops do not include field crops such as: field corn, cereal crops, perennial legumes (e.g. alfalfa) or soybeans.	The Guidelines specify a 1-year waiting period for vegetable crops. The waiting period is extended for root crops which may carry soil, based on the survival time of parasites (Feachern in Albin 1999, Larkin et al in Cliver 1980, Little 1980, and Bitton 1984).	City doesn't spread on vegetable crops for 1 year.	✔		
	Land Use Restrictions	Table 7 outlines spreading restrictions related to public health. The waiting period for pasture ranges from 2 to 6 months.	Land will not be used as pastureland for a minimum period of 5 years following land application.	Biosolids provide a potential pathway for persistent organics into the food chain via ingestion of soil by grazing animals. Cameron et al (1997) indicate a dairy cow may ingest about 900 g soil/day. There is insufficient research to establish the significance of this pathway and the appropriate waiting period. This BMP is proposed on a trial basis subject to amendment following further	Occasionally spread on pastureland.	✔		

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Program Element	Item	MOE Guideline	BMP	Basis / Rationale	Current Practice	Health Protection	Transparency	Conservative Approach
				research.				
	Soil Depth/Type	Soil criteria are addressed in Section 6.2. This BMP is intended to ensure the site is likely to meet the requirements of soil type, slope and depth based upon a preliminary inspection	Soil maps are reviewed to determine whether there is likely to be adequate and suitable (i.e. mineral) soil. Visual inspection of the soil type may be used instead of soil maps.	Good soil maps are available for the Ottawa Carleton area that can be used for a broad screening of site suitability.	Methodology not standardized.			✔
Site Assessment and Certificate of Approval Preparation	Overview			Designed to ensure that compliance with provision of the Guidelines can be documented. Provides for informed consent from the landowner and in the case of leased or rented land, acknowledgement that the farm operator has been informed of the conditions for application.				
	Soil depth	Section 6.13 addresses separation distance to bedrock. The Guideline requires 1.5 meters or soil depth and allows shallower soils to be evaluated on a case by case basis This BMP provides a basis for evaluating and documenting the soil depth.	Soil depth is a minimum of 1.5m as measured by one test hole drilled per ten hectares evenly distributed over the property (minimum one location per site). Locations of test holes are indicated on the site plan. Where rock outcrops are visible, the location at which the soil depth reaches 1.5 m is indicated on the site plan. Biosolids are not spread where the soil depth is less than 1.5m.	The Guidelines require a soil depth of 1.5m. The MOE will consider shallower depths on a case-by-case basis but this is not considered a BMP due to the increased the risk of preferential flow to the water table. The sampling density of one hole per 10 hectares is the same as the sampling density from the Guidelines (Section 1.5, Appendix I-1) for pH and phosphorus.	Methodology not Standardized.			✔
	Field Measurement	Means and accuracy of field measurement are not addressed in the Guidelines.	The field and buffer areas are measured to within 5% of actual using differential GPS or air photos and software capable of calculating the area. Once buffer areas have been identified, their area is accurately measured and deducted from the total field area. Alternatively, the maximum application rate can be reduced to 7.0 dry t/ha.	If the spreadable area of a field is overestimated by 5%, the solids content of the biosolids is underestimated by 1% and the target application rate is 7.6 dry tones per hectare, the actual application rate will be 8.3 dry tones per hectare, which exceeds the maximum application rate of 8 dry tones per hectare. Measurement of field size from an air photo, especially an irregularly shaped field will not result in the desired accuracy.	Methodology not Standardized.			✔

TABLE 7-1
Interim Best Management Practices for the City of Ottawa
Site Selection and Approval, Spreading, Inspection and Monitoring, Source Controls, Communications, Incident Response, Training

Program Element	Item	MOE Guideline	BMP	Basis / Rationale	Current Practice	Health Protection	Transparency	Conservative Approach
	Separation Distance to Population Centre		See: Pre-Screening.					
	Landowner consent	Currently, the landowner signs the application form, indicating consent to use his land for biosolids application. The BMP provides for a more informed consent as well as for acknowledgment of a leaser, where the farm operator is different from the landowner, of the conditions for application.	Signed consent is obtained from the landowner indicating an understanding of: • Waiting periods • Crop restrictions • Specific area where biosolids will be spread (shown on site plan) • Amount of nutrients being provided by biosolids • Where the landowner is different from the farm operator, the farm operator will also sign to indicate understanding of the above items.	Improved documentation of informed consent. Verification that the farm operator has been informed of the conditions of application.	Landowner only signs application for Certificate of Approval.		✔	
	Flood Plain Location	Not addressed in the Guidelines	Areas will not be selected that are subject to frequent flooding (annual or biannual) based on visual observations or flood plain mapping. Where a portion of the site is subject to flooding as defined above, it will be delineated on the site plan and excluded from the spreadable area.	Reduced likelihood of unintentional movement of biosolids into surface waters in the spring.	No current practice.			✔
	Site Plan	A site plan is required for a Certificate of Approval application. The BMP provides explicit direction on what should appear on the site plan.	An accurate site plan is produced, to scale, clearly delineating: • Site boundaries • Buffer areas • Topographical features • Location of population centres • Water wells • Surface water • Test hole locations • Staging area	Improved communication of field characteristics.	Methodology not standardized.			✔

TABLE 7-1
Interim Best Management Practices for the City of Ottawa
Site Selection and Approval, Spreading, Inspection and Monitoring, Source Controls, Communications, Incident Response, Training

Program Element	Item	MOE Guideline	BMP	Basis / Rationale	Current Practice	Health Protection	Transparency	Conservative Approach
			• Field entrance • Proposed stockpile location if applicable					
	Separation Distance to wells	The Guidelines separation distance is 15 to 90 meters, depending upon well type.	Spreadable area is calculated based on the Guidelines and a 90m separation from all wells, regardless of type or depth.	While a reduced separation distance is allowed under the Guidelines for drilled wells deeper than 15m, in practice it is often difficult to verify the depth of well.	90m separation distance for all wells.			✔
Pre-Spreading	Overview			Verification that Certificate conditions are met Practices to limit public exposure				
	Soil pH	Soil pH analysis may be up to three years old.	The soil pH measured according the Guideline requirements (one sample per 10 ha) is verified, according to Standard Methods, no more than 4 months prior to spreading.	Soil pH can vary from one year to the next. Maintaining a soil pH greater than 6 is required for compliance and is based on restricting mobilization of metals.	Guideline.			✔
	Groundwater Depth	0.9 meters of unsaturated soil at time of application.	Test holes are drilled to a depth of 1 m at a minimum frequency of one sample per 10 ha, no more than 4 weeks prior to spreading. Where there is less than 0.9m of unsaturated soil, the area is delineated and biosolids are not spread. Test holes are filled and tamped at 0.3 m intervals.	The Guidelines (Section 6.12) require 0.9m of unsaturated soil, but no sampling requirements are specified. Filling and tamping of test holes reduces the risk of preferential flow pathways from the surface to the subsurface water. The BMP provides direction on how and when the depth of unsaturated soil should be measured.	Yes, but methodology not standardized.			✔
	Resident Notification	Not required.	Residents within 450m of the spreading site are notified no less than 2 weeks and no more than 8 weeks prior to spreading. Notification includes: • A copy of the site map • Estimated start and duration of operation • Contact name and number at the city • Contact name and number for the Contractor	City of Ottawa's commitment to an open and transparent program.	Yes, but methodology not standardized.		✔	
	Well Testing	Not required.	Well-testing requested for wells that are located on lots that are adjacent to land application sites are tested for indicator bacteria, nutrients and metals	According to a groundwater quality survey carried out in Ontario in the early 1990s, approximately 50 percent of rural wells are contaminated. (Goss,	Yes, improved methodology re: sample location.		✔	

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Program Element	Item	MOE Guideline	BMP	Basis / Rationale	Current Practice	Health Protection	Transparency	Conservative Approach
			within 4 weeks prior to application. Samples are taken from an indoor tap prior to water softening (if any). Wells are re-tested between 10 and 12 weeks following land application.	personal communication) Englebrecth (1978), Cameron et al, (1997), Gerba (*in* Smith 1996) indicate that a buffer of 90 meters from biosolids spreading is sufficiently protective of wells where the ground water is in soil (not fractured bedrock). The period of 8-12 weeks has no scientific basis at this time. It was selected based on feedback from Ottawa rural residents, and allows some travel time for water to potentially move from the spreading site to the well.				
	Signs	Not required.	Signs are posted by the time spreading commences, indicating that biosolids have been spread on the field. The signs provide a contact telephone number at the city and 'Caution"  Signs are posted at the entrance to the field from the road and at regular intervals where the field is bordered by a public roadway. The signs are maintained for one year following application.	Signs provide: Advertising for the program Contacts for inquiries/complaints Caution against walking in the field. Biosolids are not suitable for public contact immediately following application. Restrict potential for public exposure to pathogens. One year is precautionary based upon pathogen survival on soil (Smith 1996, Little, Albin 1999) and consistent with National Manual of Good Practice for Biosolids	Yes, but signs do not indicate restricted access.	✔		
	Pre-spreading Checklist	Not required.	Pre-spreading checklist is completed by the contractor for each site indicating: • Buffers have been flagged • Date/method of resident notification • Wells have been tested, unless declined by the resident • Unsaturated soil depth has been verified • Soil pH has been verified • The spreadable area • Application rate • Total tonnage	Improved documentation of suitability of site conditions prior to spreading			✔	

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Program Element	Item	MOE Guideline	BMP	Basis / Rationale	Current Practice	Health Protection	Transparency	Conservative Approach
			• The anticipated start date • The checklist is submitted to the city prior to spreading.					
Spreading	Stockpiling	Not addressed in the Guidelines.	Cover stockpiles with a contiguous cover of soil, hay or other approved material. A 450-meter minimum separation distance is provided from an individual residence. A 450-meter minimum separation distance is provided from a population centre.	Stockpiles are a source of odours. Covering the stockpile reduces odours. The enhanced separation distances were selected for Ottawa to limit public exposure to stockpiles odours as a “good neighbour” policy.	Stockpiles are covered. Distances not standardized			✔
	Application Rate	Guideline is 8.0 t/ha.	The targeted application rate does not exceed 7.6 t/ha.	5% safety factor is applied to the spreading rate to reduce the risk that the Guideline is exceeded.	Methodology not standardized			✔
	Weather during spreading	Not addressed in the Guidelines.	Spreading does not proceed when the wind speed is sufficient to disrupt the spreading pattern. Spreading does not proceed in rain conditions heavy enough to cause runoff or soil saturation.	Uneven distribution of the biosolids can affect crop nutrient availability and uptake. Strong winds can carry odours and generate complaints. Ottawa has adopted this measure as a “good neighbour” policy. Runoff conditions from the field increase the possibility of surface water contamination. Spreading on saturated soil can cause soil compaction.	No current practice			✔
	Hauling	Not addressed in the Guidelines.	Biosolids loads are tarped during transport. The truck is inspected prior to entering public roadways to ensure biosolids are not present on the outside of the truck. Any biosolids inadvertently tracked onto public roadways is removed immediately.	Tarping minimises odour and prevents material loss during hauling. Biosolids that fall from the truck onto public roadways represent a potential pubic exposure pathway.	Current practice to tarp. Inspection and cleanup not explicit in contract.	✔		
	Incorporation	Normally 24-hour incorporation.	Incorporation normally occurs within 2 hours of spreading No more than 5% of the biosolids remain on the	Incorporation minimises odours, prevents runoff, reduces generation of biosolids dust which may become airborne, improves contact between soil and biosolids to reduce contaminant mobility, and	Typically occurs within 2 hours. No standard re:			✔

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Program Element	Item	MOE Guideline	BMP	Basis / Rationale	Current Practice	Health Protection	Transparency	Conservative Approach
			surface after incorporation.	improves nutrient availability. There is currently no definition of "incorporation". The visual measure of no more than 5% remaining on the surface is recommended on a trial basis.	incorporation.			
Post-Spreading	Site Condition	Not addressed.	Field entrance, staging area and public roadways have been returned to their previous state. There is no biosolids on the road.	Tracked biosolids is a direct pathway of public exposure. Field damage will affect program credibility	No standard procedure.			✔
	Well Testing		See: Pre-Spreading.					
	Post Spreading Checklist	Not required.	Checklist is completed by the contractor for each site indicating: • A visual confirmation that all biosolids has been incorporated • Quantity of biosolids applied • Area applied • Date started and completed • The checklist is submitted to the city within 24 hours.	Documentation of post spreading information The city is kept informed of the contractor's activities.	No standard procedure.		✔	
Inspection and monitoring	Overview			Documented inspections to demonstrate compliance with regulatory requirements and Best Management Practices Monitoring to assess environmental impact of practices				
	Pre-Spreading Checklist		See: Pre-spreading.					
	Post-Spreading Checklist		See: Post Spreading.					
	Well Monitoring		See: Pre-spreading.					
	Site Inspection	Not required.	All sites spread during one season are inspected, either pre, post, or during spreading, by qualified	The contractors activities must be inspected to demonstrate conformance with C of A	Current practice.		✔	

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Program Element	Item	MOE Guideline	BMP	Basis / Rationale	Current Practice	Health Protection	Transparency	Conservative Approach
			party independent of the contractor for conformance with the Certificate of Approval requirements and the city's Best Management Practices. Verification records are maintained by the city.	requirements and BMPs.				
	Biosolids Quality monitoring	Once per month when biosolids are being spread and twice within the two month period prior to land application (Appendix I-7 3.4.2).	A grab sample of biosolids is sampled and analysed for the regulated parameters no less frequently than once every 2 weeks. Results are reviewed by the city on a bi-weekly basis during spreading season.	The hydraulic retention time of the digesters is approximately 20 days. Based on a the behaviour of a completely mixed system, a sampling frequency of no less than once every 15 days would result in three consecutive elevated samples as the result of a single "spike load" to the sewer. Monitoring provides data on both long term trends and short term events. This data can be used to estimate metals loadings to fields.	Weekly sampling. (BMP is as effective as current practice).			✔
Source Controls	Overview			Biosolids quality is a reflection of what is discharged to the sewage system. In many cases, it is more appropriate to prevent discharge of a contaminant in to the sewage system through source controls rather that attempting to remove the contaminant through sewage treatment.				
	Take it Back Program	Not addressed.	The city maintains a "Take it Back" program for used drugs.	Some pharmaceuticals entering the sewage treatment plant partition with the biosolids. The implications of pharmaceuticals in sewage is currently being investigated by the scientific community. Proper disposal of used drugs reduces this pathway into the environment.	Yes.			✔
	Industrial Source Controls	Not addressed.	The city continues to strengthen its Industrial Waste Sewer Use Control program.	At source reduction of metals and other targeted pollutants is the most effective means of controlling their entry into the environment.	Yes.			✔
Communi-cations	Overview			Effective communication with the public will support program credibility Program transparency is an important component of the Ottawa program				

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Program Element	Item	MOE Guideline	BMP	Basis / Rationale	Current Practice	Health Protection	Transparency	Conservative Approach
	Resident Notification		See: Pre-spreading.					
	Complaint Response	Not addressed.	All complaints are handled by city staff (TUPW and Public Health). All complaints are followed-up within 24 hours of receipt. All complaints are logged in a standard manner and maintained in a central registry.	Complaints handled in a consistent and efficient manner by the city will support program credibility.	Current practice but not standardized.		✔	
	Information Management	Not addressed.	Data from pre and post inspection reports is logged, including: • Dates of well testing • Resident notification • Lot and concession of site • Date of start and end of spreading • Area spread • Total volume spread • Rate of spreading • Nutrient and metals loading	The creation of a database will facilitate access to information by program managers. This data could eventually be integrated with a GIS system that includes geo-referenced maps of each site.	Current practice but not standardized.		✔	
	Availability of Information	Not addressed.	All of the information with the exception of protected personal information is easily available for public inspection. An “Issues Matrix” of concerns raised by the public and the city’s responses is maintained and readily available.	Program transparency	Current practice but not standardized.		✔	
Incident Response	Overview			Incidents are tracked and responded to in a consistent manner				
	Well contaminatio		In the event that a drinking water well sample result is greater than a the Maximum Acceptable	Protection of public health in the event of contaminated well water and confirmation of	Notification is practised but procedures not	✔		

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Program Element	Item	MOE Guideline	BMP	Basis / Rationale	Current Practice	Health Protection	Transparency	Conservative Approach
	n		Concentration or Interim Maximum Acceptable Concentration indicated in Tables 1 and 2 of the Ontario Drinking Water Objectives, the following steps will be taken: • The laboratory will immediately notify the designated city program manager by telephone. • The designated city program manager will immediately notify the well user, by telephone or in person of the sample result and advise the well user not to consume the well water. • The designated city program manager will notify the designated Health Department person. • The designated city program manager will arrange to collect two confirmation water samples from the suspect well one within 24 hours of being notified of the suspect result, a second within 72 hours. • If the two follow-up samples are clean, the well user is notified of the result and there is no further action. • If one or both of the follow-up samples confirm the initial result, the resident is notified of the result and referred to the Health Department for assistance. • The date and time of all communication and actions is logged.	results. Information is logged to allow verification of incident chronology	standardized.			
	Public Health Incident	Not addressed.	When an individual or group of individuals reports adverse health effects from exposure to biosolids: • The Manager of Environmental Health (Department of Health and Long Term Care) is notified and contacts the individuals concerned. • The Biosolids Program manager is notified.	The city has an obligation to thoroughly investigate any health-related complaint. Tracking and investigating heals-related complaints can be used to demonstrate program safety.	Procedures not standardized specifically for biosolids.	✔		

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Program Element	Item	MOE Guideline	BMP	Basis / Rationale	Current Practice	Health Protection	Transparency	Conservative Approach
			• The health-related complaint is investigated to determine the diagnosis and cause of illness (if possible) • An incident report is prepared including the incident chronology, biosolids spreading conditions, and outcome. • Other action is taken as deemed appropriate by the Department of Health and Long Term Care.					
	Spill	MOE Spills Response Procedure.	A spill is defined as a discharge of a pollutant into the natural environment … that is abnormal in quantity or quality. Spills must be reported if they … cause or are likely to cause any of the following: • Impairment to the quality of the natural environment - air, water, or land • Injury or damage to property or animal life • Adverse health effects • Safety risk • Making property, plant, or animal life unfit for use • Loss of enjoyment of normal use of property • Interference with the normal conduct of business • In the event of a spill, the following steps will be taken: • The spill area is contained to restrict public access. • The spill is contained where possible to prevent movement to surface or ground water. • The contractor notifies the designated city program manager.	Effective, consistent and efficient approach to spills will provide program credibility Demonstrates due diligence to regulator	Contractor is required to have a spill response procedure.	✔		

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Program Element	Item	MOE Guideline	BMP	Basis / Rationale	Current Practice	Health Protection	Transparency	Conservative Approach
			• The contractor notifies the Spills Action Centre. • The contractor cleans up the spill in consultation with the city. • Where there has been movement of biosolids into the natural environment, samples will be collected to assess the extent of contamination. All data collected are provided to the Ministry of Environment. Incident report and chronology is logged.					
	Off-Spec Biosolids / Over Application / Application in Restricted Zones	Not addressed.	In the event that off-spec biosolids are applied, or biosolids are over applied or applied in restricted zones: • The Ministry of Environment is notified. • The root-cause of the non-conformance is identified. • Affected areas are sampled as per Section 1.1 of Appendix I-1 of the Guidelines. Samples are analysed for the 11 control elements and pH. • The data are provided to the Ministry of Environment for further action as necessary.	Off-spec biosolids are those that do not meet the quality criteria of the Guidelines outlined in Tables 1 and 2 Sampling provides the city and the Regulator with data for assessment of potential environmental impacts.	No standardized procedure.			✔
Training	Overview							
	City Staff	Not addressed	All city staff who are involved in the program, especially those who may have contact with the public are provided training on the Guidelines and the Best Management Practices.	Staff who are involved in the program are knowledgeable and are able to answer public inquiries or know where to send the inquiry.	No standardized procedure.			✔
	Contractor	Not addressed	Contractor staff are provided training so that they are knowledgeable of the Guidelines and Best Management Practices Contractor staff, especially operational staff who work directly with biosolids are provided Health and	All contractor staff are aware of Guideline and BMP requirements. Contractor staff has appropriate H&S training.	No standardized procedure.			✔

TABLE 7-1
Interim Best Management Practices for the City of Ottawa
Site Selection and Approval, Spreading, Inspection and Monitoring, Source Controls, Communications, Incident Response, Training

Program Element	Item	MOE Guideline	BMP	Basis / Rationale	Current Practice	Health Protection	Transparency	Conservative Approach
			Safety training on proper biosolids handling practices, personal protective equipment and hygienic practices.					

Appendix A
Interview Transcripts

The information presented in these transcripts has not been critically reviewed by Apedaile Environmental and CH2M HILL Canada Limited. The information is intended for the sole use of the Medical Officer of Health in his determination regarding the safety of land application of sewage biosolids for the City of Ottawa. The opinions and views expressed in the interviews are those of the authors and not of the city and its consultants. The city and its consultants take no responsibility for the accuracy or correctness of the information.

Interview Transcript

Call To: Dr. Rufus Chaney, U.S. Dept. of Agriculture, Environmental Chemistry Laboratory

Phone No.: 1-301-504-8324 **Date:** February 07, 2002

Call From: Erik Apedaile, Susan Liver, Irwin Osinga **Time:** 09:30 AM

Message Taken By: Susan Liver

Subject: Health Aspects of Biosolids Land Application

Reviewed and revised by R.L. Chaney, March 5, 2002.

EA Provided an overview of the project and using the WEAO as a launching point.

RC I led the 503 scientific team which prepared the PCB Pathway calculation methods and estimated limits. This methodology is certainly applicable in terms of the approach to other lipophilic, persistent xenobiotic compounds. I believe the PBDEs are not claimed to be carcinogenic, but are estrogenic and bioaccumulative if ingested. The more lipophillic the compound, the more it is adsorbed to biosolids or soil organic matter – and the adsorption can reduce bioavailability quite a bit. Not too much information is available on PBDEs. The recent press on PBDEs shows small concentrations in biosolids and high levels in fish. There has been no evidence of a connection between biosolids use and fish exposure/accumulation of PBDEs. But lots of negative statements toward biosolids. These compounds are used in consumer products of many kinds, so human exposure is hardly related to biosolids in any way. Ingested lipophilic materials are biomagnified in aquatic food-chains, so PCBs, PBDEs, and similar compounds can reach high levels in predator fish. After biosolids are incorporated in soils, soil ingestion is the only pathway which could give measurable transfer, and that would be small.

EA What pathways are there to the human diet for such lipophilic compounds?

RC Strongly bound lipophilic materials such as PCBs have low transfer to forage crops or even garden foods. Carrot skins accumulate measurable amounts from PCB amended soils, but other foods are not detectable affected at the levels allowed by present regulations.

But when the fluid biosolids are spray applied on standing forages, the biosolids particles can get stuck on the forages [Chaney, R.L. and C.A. Lloyd. 1979. Adherence of spray-applied liquid sewage sludge to tall fescue. J. Environ. Qual. 8:407-411.]. When such contaminated forages are grazed, livestock can get high exposure to xenobiotics in biosolids. If dewatered biosolids or composts are land applied, the biosolids fall to the soil surface rather than get spread out on leaves and stems of forages, and exposure is hardly different from the ingestion of surface soil model. If the biosolids are incorporated into soil, uptake to forages is low, but soil ingestion does allow some livestock exposure and absorption of xenobiotics. Grazing (not forage uptake) by animals could be getting these compounds into food and milk, especially if the biosolids are surface applied.

IO So a BMP would be to not apply biosolids to pastureland

RC The BMP is to incorporate the biosolids if the field will be used for pasture. Biosolids can represent 12% of an animal's diet if fluid biosolids are surface applied (part gets stuck on the crop) vs <<1% if incorporated (animals consume about 1.5% soil on yearly average basis; and if biosolids are mixed with soil, the surface soil to which they have access contains greatly diluted biosolids. See the data summarizing chronic season long grazing exposures in our paper on PCBs.

EA How do you think compounds like PBDEs are showing up in human breast milk ?

RC Probably through exposure to consumer products which contain the PBDEs, or through eating fish. That's why urban runoff is very important to control of this exposure. Sources are probably from sewage treatment plants and urban runoff. The penta-Br group [of PBDEs] is much more transferable than the deca-Br group. The higher chlorinated or brominated compounds are much more strongly bound to soil. They stay largely in the soil where they are applied.

IO Is there a potential for BDE limit in US ?

RC I think it's a matter of time. Much more data are needed before a limit can be set. I think they will prohibit manufacture first, long before EPA could propose, revise and promulage limits for another organic compound in biosolids. We've got PCBs <<1 ppm (dry weight basis) [in US biosolids] because their manufacture and use was prohibited. It depends what individual countries allow these compounds to be used in. Stop putting them down the sewer, using them in the home. If you want a good PCB sample, go to an old house … much higher levels than industry where they are no longer used.

IO One of recommendation from WEAO report regarding non-regulated metals is to take a no net degradation approach. This could severely limit Ag, Tl, Sb loadings.. The number of applications could be limited to as low as one lifetime application.

RC I think one needs to look at risk assessment instead of "no net degradation" to make judgements about limits for metals. And the key for regulation is bioavailable element in biosolids-amended soil. If a metal is not bioavailable from soils or biosolids, it is not a source of risk. Silver is present in soil everywhere at low levels. It's extremely immobile in soil. You need to see a harm in a high end exposure scenario before you decide to regulate. But Ag is extremely toxic if you dissolve it (e.g., $AgNO_3$) and inject it into blood, or add soluble Ag to pure water for fish. But it is hard to get Ag from soil to humans otherwise. There is no evidence that there is a risk from biosolids Ag at any level.

Until you have reason to believe that there is a risk to humans from the highest transfer pathway, you shouldn't be regulating it. It's like Zr, Sn, Cr(III), Ti, etc. – not soluble. Do you want to regulate Si in soil which are high in Si?

With respect to Sb, there's lots of data which indicates that if Sb in biosolids is above background soil level there is still no transfer into food chain for crops grown on biosolids-treated soil. The paper by Chaney et al. (1978) [Chaney, R.L., G.S. Stoewsand, A.K. Furr, C.A. Bache and D.J. Lisk. 1978. Elemental content of tissues of Guinea pigs fed Swiss chard grown on municipal sewage sludge-amended soil. J. Agr. Food Chem. 26:944-997.] show results for Sb. Plants were not increased by adding biosolids-Sb to soil; and animals did not accumulate Sb at levels in the plants. Sb mine wastes is the only case we've seen -- where wildlife had exposure, and that resulted from soil ingestion from very high soil concentrations. The amount in biosolids vs background soils is not significant and doesn't transfer. It's like Ag, vanadium and many other elements. If one compares the concentrations of Ag, Sb, and Tl present in background soils (see USGS data in file I sent earlier) to the levels present in biosolids, it is evident that high cumulative applications of biosolids will have little effect on soil composition. And research has shown low transfer of these to foods and low risks in foods.

Opposite of this pattern of insolubility limiting food-chain transfer is elements such as Cd which is actually mobile. But as I have shown in the papers I sent you, when biosolids have their normal 1 Cd to 100 Zn, bioavailable Cd in crops is kept at low background levels by competition between Zn and Cd. This is important for understanding that eating higher amounts of vegetables and whole grains grown on biosolids amended soils does not threaten higher Cd risk because the bioavailability of Cd in the foods is near zero because of the other nutrients and sorbents in foods. In the paper cited above regarding Sb transfer thru garden crops (Chaney et al., 1978), we had up to 5-fold higher Cd in Swiss chard grown on an acidic soil with high biosolids application, but Zn was similarly increased. And there was no increase of Cd in kidney or liver, the measures of Cd accumulation in animals. Thus the application caused no increase in bioavailable Cd when crop Cd was 5-fold increased. This kind of result is why we focus on bioavailability of the contaminant.

For chromium the form is chromic in sludge, not chromate. No indication of it being mobile. Some natural soils >1% Cr. [see attached review on Cr in biosolids; Chaney, R.L., J.A. Ryan and S.L. Brown. 1997. Development of the US-EPA limits for chromium in land-applied biosolids and applicability of these limits to tannery by-product derived fertilizers and other Cr-rich soil amendments. pp. 229-295. *In* S. Canali, F. Tittarelli and P. Sequi (eds.) Chromium Environmental Issues. Franco Angeli, Milano, Italy [ISBN-88-464-0421-1].]

Copper is most limited by phytotoxicity. Plants are killed before the concentration is dangerous to people. Good information about Cu transfer and risk are reported in: [Minnich, M.M., M.B. McBride and R.L. Chaney. 1987. Copper activity in soil solution. 2. Relation to copper accumulation in young snapbeans. Soil Sci. Soc. Am. J. 51:573-578.]

and in a paper by Webber et al.: [Webber, M.D., Y.K Soon, T.E. Bates, and A.U. Haq. 1981. Copper toxicity to crops resulting from land application of sewage sludge. pp. 117-135. In P. L'Hermite and J. Dehandschutter (eds.) Copper in Animal Wastes and Sewage Sludge. Reidel Publ., Dordrecht.]

IO What about the fertilizer and compost guidelines for copper at 757 mg/kg TS and 100 mg/kg TS.

RC The Canadian compost guideline has no scientific basis whatsoever. It was selected to discriminate between composted materials, which have higher Cu than background plant debris composts, such as swine manure, and biosolids. Work done by Ag Can in the Maritimes showed you need to add copper to peat to get it to grow anything, and that quite high soil Cu can be non-phytotoxic even in acidic soils. [See papers by Mathur et al.]

There was a paper by Sebastien Sauvé in Montreal – examining phytotoxicity from urban garden soil [Tambasco G, Sauvé S, Cook N, McBride M, Hendershot W. 2000. Phytoavailability of Cu, Pb and Zn to lettuce (*Lactuca sativa*) in contaminated soils. Canadian Journal of Soil Science 80:309-317.] Some garden soils had Cu levels >1000 ppm because of what people have added to their gardens over the years, but the copper didn't transfer into the garden food. Webber et al. (1981, cited above) reported their examination of potential for Cu phytotoxicity from biosolids. Until they had about 8000 ppm Cu in the biosolids, they did not cause phytotoxicity. And biosolids cause only a small increase in the Cu levels in crop tissues. When scientists study freshly added Cu-salts rather than insoluble Cu in biosolids or manure, they get a lot of artifacts, which suggest toxicity would occur in the field. But long-term field tests with biosolids, and use of biosolids to remediate Cu toxic smelter contaminated soils show that Cu in biosolids has low phytoavailability. I think sludges shouldn't be over 500 Cu because that level is attainable with reasonable pretreatment enforcement, or by controlling the drinking water aggressiveness and alkalinity so pipes are not corroded.

EA In Ontario soil pH needs to be 6.

RC Reg 503 doesn't have a pH limit. But the EPA reg assumes that if the soil pH falls below 5.5 that the farmer needs to do to deal with Al and Mn toxicity in the soil by adding limestone. That need for pH near 6.5 is greater for garden crops and legumes than for cereals.

EA What is a dangerous soil pH?

RC At 5.2 you get yield reduction from Al toxicity; soil Al dissolves and become a significant part of the exchangeable cations. Most crops suffer from soluble Al.

EA Any evidence of humic acid increasing metal solubility in A [soil] horizon ?

RC Only when we lime. The higher pH caused dissolution of more of the fulvic and low molecular weight humic materials and these carry Cu. We were able to measure 1-2 ppm increase in subsurface soil (upper B Horizon) Cu concentration. However this is 1-2 ppm compared to background of 15-25 ppm. Other metals were less increased, and even the Cu movement is not evidence of risk transfer or mobility of concern. [see: Brown, S.L., R.L. Chaney, C.A. Lloyd and J.S. Angle. 1997. Subsurface liming and metal movement in soils amended with lime-stabilized biosolids. J. Environ. Qual. 26:724-732.]

We're not concerned about the unregulated metals because we don't have technical evidence which would give us a reason to be concerned. We've suggested that Fe needed regulating because (ferrous in digested sludge) can cause cattle poisoning (if surface applied). Even dewatered biosolids spread on surface gives much lower transfer of metals in the biosolids into cattle diets than liquid biosolids. The dewatered biosolids don't cover the entire plant material, as I noted above about PCBs.

I also suggested risk assessment for Co – just to check that we don't have a rare high Co risk in sludge in a particular area. Plants can take up enough Co to harm ruminant livestock under worst case model conditions. There has never been a case to justify this concern, but theoretically ruminants could be at some risk. But not consumers of the cattle.

EA What are the implications of this for Ottawa ?

RC I think you should make an issue of voluntarily giving up the right to surface apply liquid biosolids. At least Ottawa needs to recommend incorporation, recommend tillage to incorporate the biosolids before growing a crop, which would be grazed. Incorporation reduces potential exposure (worst case models) remarkably. Look at the Pathway PCB limits for surface applied vs. incorporated biosolids.

If you give up pastureland it reduces flexibility. I recommend as a guidance all biosolids be incorporated before grazing occurs. Standing crops with sprayed liquid can result in 25% sludge in diet. Incorporation results in less exposure for metals, organics, pharmaceuticals, and odour. It is a BMP! But the same application in a remote location to grow grain crops may be the least expensive alternative and should be considered where it is available.

IO What about improvement of the Sewer Use Bylaw ?

RC We recommend a difference between 503 quality and target quality for biosolids to be applied on farmland. Pretreatment can easily produce better quality biosolids. I have called these "Attainable Limits" which should be readily reached by any POTW. The cumulative limits in high quality biosolids do not comprise risk to fertility or food-chain safety, or environmental receptors. Although the higher limits of 503 can be tolerated by society, but if you can avoid putting these metals down the sewer it's better. We have recommended "attainable" levels eg. Hg 2-5 mg/kg vs 20 mg/kg in Reg 503, 500 mg/kg Cu vs. 1600 ppm in 503, etc. The "attainable" levels are always better than the max allowed by 503.

Have you seen the paper by Li, Ryan et al. (2001)? [Li, Z. Li, J.A. Ryan, J.-L. Chen and S.R. Al-Abed. 2001. Adsorption of cadmium on biosolids-amended soils. J. Environ. Qual. 2001 30:903-911.] They have proven the inorganic matter in biosolids increases the ability of soils to bind heavy metals. Cornell (McBride and others) are wrong about the "Time Bomb" claim they made. If you add Fe or Al to lessen P release from the STP, you have more metal adsorption in the biosolids and reduced metal transfer and bioavailability.

IO Ottawa uses ferrous chloride for P removal.

RC The [Washington] DC plant uses this and had very substantially increased adsorption. The fear of disappearing organic material releasing the metals overtime is wrong. Metal adsorption is increased by the inorganic fraction.

IO Ottawa Fe is 70,000 mg/kg (7%) which is about double the provincial average.

RC Fe in biosolids is typically about 20,000 mg/kg dry weight. Our work found biosolids causing harm to cattle when fluid biosolids were surface applied on pastures, which contained about 120,000 mg Fe/kg (12%). Ferrous was solublized in the rumen. It induced copper deficiency in the cattle. The first year of that study we applied fluid biosolids one day before or 21 days before cattle came in. This proved you shouldn't be allowed to surface apply high Fe fluid biosolids.

EA The cattle didn't get sick from pathogens

RC No, didn't get sick from pathogens. Well digested sludge has low innoculum potential for most pathogens. At 4% iron in the sludge there was no problem even when it was surface applied on pasture. Compost with at least 5% Fe gave no problem. Only spray applied fluid biosolids was an issue. The 30 day waiting period would be important to minimise transfers from surface applied biosolids.

Again, the idea of incorporation is important – particularly regarding the idea of unknown organics – incorporation reduces the transfer to livestock very strongly.

IO I'm assuming the Dow Chemical herbicide , Clopyryalid is not a concern in biosolids

RC No one has seen toxicity from this in biosolids. I'm sure it's detectable because the vapour pressure is high enough.

EA Is it common to use chain harrows to spread lime stabilized sludge (dewatered)?

RC It is done, but not common. Some cities simply inject all fluid biosolids to prevent these exposure and odour concerns. For surface application, malodour, and the potential for runoff means more set backs are needed. If rules are followed it's ok. Over time, it's better to incorporate. Better for the phosphorus control too. Much better for public perception.

EA Any other references we should contact ?

RC Jim Smith with the EPA in Cincinnati has a lot of experience with pathogens and common sense. You know the New Hampshire case was settled ?

EA It would have been better to finish the case. Leaves fewer questions. I was surprised about the way the biosolids were applied.

RC That is certainly not the worst case. Improper management is a serious problem if States do not have enforcement capability. But most problems have been prevented by normal State and County regulation and enforcement. When a larger city ships biosolids some distance to reach arable land where the nutrients are needed, it is often aided by a fee for each tonne of biosolids generated; the fee is used to support local environmental or health department inspectors to assure sites are appropriate, and that unannounced inspections can occur to discourage violations.

IO Certainly dewatered cake from high solids centrifuges stink.

EA Do you have an opinion on Class A versus B ?

RC I stand by waiting periods and Class B biosolids, if acceptable to land users and neighbours re: odours etc. Class A biosolids products are more favorable for public acceptance. For Class B biosolids, there is a 3 year wait for food crops that are marketed uncooked (eg. potatoes), not processed foods like beans. Processed foods like grains are covered by a husk so there is no pathway. I don't know of a reason to be concerned with properly managed Class B biosolids even though Class A gives more flexibility and better public acceptance.

Chaney also described an extreme worst case Cd and Zn contaminated soil surrounding a smelter in Pennsylvania. The garden soils reached over 100 ppm Cd and 10,000 Zn. People grew gardens for decades. But an epidemiological study of older women found no adverse effect on this population. High quality biosolids do not comprise a Cd risk to humans or wildlife for the reasons I summarized in the papers I had sent you.

Interview Transcript

Call To: Dr. Michael J Goss, Chair of Land Stewardship, University of Guelph

Phone No.: (519) 824-4120 x2491 **Date:** January 30, 2002

Call From: Erik Apedaile (EA) , Susan Liver (SL) **Time:** 09:00 am

Message Taken By: Susan Liver

Note: This record is intended to capture the essence of the discussion and is not intended to be a verbatim record of the conversation.

EA provided an overview of the Biosolids program in Ottawa and the approach for this project.

Summarize your current research / work into health-related aspects of biosolids land application.

MG I was heavily involved in 1991-92 farm ground water (gw) quality survey. Found manure was a very important factor. A gap was identified with respect to health issues related to indicators of fecal contamination of water supply and the pathways to the wells. Most of the effort was related to manure aspects (not biosolids) with the exception of whether contamination is coming from a septic system rather than manure.

We did look at nitrates in gw and whether this was from biosolids, septic systems or manure.

EA What proportion of wells were contaminated from the survey ?

MG About 50% overall: 40% with nitrate, 0.3% with pesticides, 1/3 with e.coli., 40-45% with total coliforms. Therefore 1 in every 2 wells exceeded the maximum acceptable concentration of any one substance at any time.

In general, the deeper the well the less likely to be contaminated. However, there was no depth or well construction which was free from contaminants. Therefore you need to be prepared to treat the water.

On drilled wells versus dug wells -- The study tried not to include wells with obvious problems. It only included wells with a reasonable expectation that the near-surface construction wasn't going to affect the water quality. It's obvious that with dug wells there is the potential for the contaminants to get in from all depths, where with drilled wells the contaminants must be coming from the gw itself.

Nitrate and Pathogen indicators were higher where manure was spread than where it wasn't.

There was no depth where indicators were not present.

Over the course of the survey we tended to see the peak in e.coli slightly later [in the year] than the peak in total coliforms.

EA For biosolids the drilled well separation distance is 15m, and a dug well is 90 m.

MG I don't believe "one number fits all" is the right approach. The type of soil differs from one area to another. In discussions with MOE about distance between wells and septic systems, we argued strongly against going for the one number approach. It should be based on geological conditions and preferential flow.

EA How would you propose to determine the separation distances ?

MG We need to think about whether we're looking at pathogens or nitrates. My view is pathogens are more serious than nitrates. If you're on sandy soils, the potential for contamination is with nitrates rather than pathogens. You could therefore spread nearer to a well than for loamy soil. You need to look at the worst case for each site.

The concern with clay and clay loams is macro-pores and fracturing.

EA Clays retain viruses.

MG Nitrates and viruses are retained by clayey soils but pathogens can be enhanced. The greater flow will tend to carry some of the viruses with them. We haven't looked at the viruses but I've worked with others who have.

EA Who should we talk to ?

MG I've been speaking with Susan Springthorpe at U of O

EA What was the nature of the [biological] well contamination ?

MG We used zero as max acceptable for e.coli and 10 for TC. We saw wells with the whole gamut of contamination. We wanted to show the integrated picture and the buildup of contamination.

SL Was the manure applied as liquid ?

MG No, both liquid and cake. We didn't get to the level of detail of looking at liquid versus solid manure spreading. In subsequent work found solid less likely to contaminate groundwater.

Ron Flemming at Ridgetown is looking at tile drain water.

We also followed up the GW study to see if people got sick or developed immunity with persistent well contamination. Found that the likelihood of gastrointestinal illness was doubled if the e.coli was present in the wells. E.coli is only an indicator. It's not that it's specifically the e.coli causing the illness. We concluded that it was an acceptable indicator for private wells. We concluded that Total Coliforms is not a useful indicator.

Subsequently we went on to see if the stratigraphy would indicate which areas would be more vulnerable. Looked at 200 wells in E Ont and 200 in SW Ont. We found that having hardpan or shale in the geology conveyed a considerable level of protection, but there was no stratigraphy which provided total protection. With hardpan, the recharge is coming from elsewhere. The further the distance from the recharge area the less likely the pathogens will survive the transport time.

We tried to divide the wells into chronic contamination and wells which were intermittent. (sampled over a 3 year period.) In the case of chronically contaminated wells, about 20% of contamination was from septic systems. Other contamination was related to manure from domestic livestock or wildlife (rodents getting into the wells.)

People far too often think the well is out of site, out of mind.

SL What are the implications regarding the stratigraphy in the Ottawa area ?

MG Depends how close you are to the sheild. Varies across the region we looked at.

EA Does a tile-drain field act as a barrier ?

MG Tile drains act as a short-circuit to the surface water. In E.Ontario, the likelihood is that a greater proportion of the water is intercepted by the tiles. The clay soils, by and large, are reasonably permeable. The tile lines don't intercept 100% of the drainage water. In places like Winchester and others, you probably do get a relatively large proportion of the water being intercepted. In SW Ontario only 40-50% of the water is intercepted by tiles.

EA Do you have advice for BMPs, especially with respect to separation distances ?

MG I would refer you to Robert Bruce, MOE. We had a round table discussion with his group and recommended that it is approached on almost a risk basis. Speak with him and see if that approach works. You can follow up with me if you need more information.

EA What direction is your work taking you ?

MG What we haven't touched on is the [bacterial] survival aspects. We think there are a number of issues related to survival that still need research. It's not clear if all the factors in survival are understood. We want to be able to predict the source strength.

Secondly, it's evident that the transport of bacteria is dependent on the soil structure and size of pathogens. We believe there are possibilities of controlling transport if we can manipulate the surface properties of the bacteria (hydrophobicity). We may be able to change the environment in which the bacteria are being transported. Liquid contains quite a lot of salts. We think there may be opportunities to manipulate the ionic environment in which the bacteria reside and therefore attach more to the soil particles. They will move down with each addition of rain but less likely to reach the tile lines or the gw. Either add something to the sludge or the soil prior to application.

The other concern is how the material is added to the land. The evidence is that injection controls odour and aerosols, but there are some issues in terms of increased preferential flow fairly close to the bottom of the A Horizon and link up with macro pores. How to inject without creating preferential flow.

We need to see if the soil is in the appropriate state to receive any type of application.

EA Are the current MOE site assessment requirements for C of A application adequate ?

MG Certainly this needs to be looked at and how to the applicators view the C of A requirements. Are they just looking for the easiest way to get the job done ?

EA In Ottawa we've been trying to get pre-spreading site-inspection to check if the site conditions meet C of A. A key element is whether there is adequate soil depth unsaturated.

MG Recommendations for manure is that the tile lines should not be running.

EA There are tiles that are always running.

MG Yes, sometimes they are intercepting springs. You need to look if that is just one tile or the whole field is wet. It's usually pretty clear.

SL You spoke about changing the ionic balance to slow the transport of pathogens. How would lime stabilization likely affect the transport ? Faster or slower ?

MG Lime stabilization would probably reduce the transport since bacteria will have a greater possibility to adsorb to the exchange sites on the soil surface if there a lot of calcium sites.

EA Do you think biosolids will be named specifically in the Walkerton Part II report ?

MG Maureen Reilly provided information to the Commission. We listed all the sources of potential water contamination and biosolids were listed as a significant source. Farmers actions were given a reasonable bill of health, but that will feature more prominently in Part II.

EA Do you have Maureen Rielly's report commissioned for the Walkerton ?

MG I've been looking for this too. I'll be talking to her soon and will ask her about this. She made a good series of contributions. I'd be happy to provide paper references.

Interview Transcript

Call To: Dr. Robert Hale,Department of Environmental Science
Virginia Institute of Marine Science
College of William and Mary

Date: 30 January 2002 **Time:** 11:00

Taken By: Susan Liver (SL), Erik Apedaile (EA)

Reviewed and revised by R. Hale 5 March 2002

EA provided an overview of the biosolids program in Ottawa and the approach for this project.

SL discussed the project context with respect to timing and the results of the WEAO review. Polybrominated diphenyl ethers (PBDEs) were not addressed in the WEAO review, but we are including them as Group II.

Summarize your current research / work into health related aspects of biosolids land application:

RH The issue of PBDEs arose in two ways. The first came from the past 12 years of working with the Virginia State Department of Environmental Quality, looking at contamination in fish tissues, focusing on conventional EPA priority organic contaminants as well as other 'early warning' contaminants. A few years ago, levels of PBDEs were discovered in fish tissue paralleling levels reported in Sweden in the early 80s. This work was focused on impacts on the aquatic environment.

The second pathway was based upon the work of Geiger et al in Switzerland. Generators did not know the levels of nonylphenols in sludges. Analysis indicated that the levels were in the parts per million to thousand. Further analysis for PCBs incidentally found a series of peaks that corresponded to PBDEs and dwarfed the concentrations of PCBs.

SL Toronto has chosen to regulate nonylphenols in their sewer use bylaw, partially driven by a movement toward land application and away from incineration. Toronto's move to regulate nonylphenols may result in other municipalities in Ontario doing the same.

RH Nonylphenols have been addressed somewhat by the regulators and have subsequently written off as not persistent, however there is the potential for additive effects with other estrogenic compounds present at low concentrations. There is published information that is not in agreement with the conclusion the nonylphenols are not persistent and that they may have an additive and cumulative effect with estrogenic compounds.

SL PBDE are showing up in fish tissue, yet they have a high octanol water coefficient – how are they getting into the lakes?

RH PBDE are slightly more bioaccumulative than PCBs. They have a log K_{ow} of about 6, which is in the optimal range for absorption. The penta formulation especially is a problem. The deca formulation is currently the most common representing 70-80% of the brominated flame-retardants used in North America. I'm not sure of the relative usage in Canada versus the U.S. So far, requests to get information on the breakdown of use of the different formulations has not been successful in the US. The PRI (Pollutant Release Inventory) lists deca so this is publicly available but information on the usage of the penta formulation has been held as confidential business information. Note: In the US this is the TRI.

In Sweden, there were concerns that the levels of Penta BDE constituents were doubling in human breast milk every two to five years. Europe has now virtually eliminated the use of the penta BDE mixture and levels appear to be dropping, while 98% of the penta BDE demand resides in North America. Sewage sludge levels of PBDEs are correspondingly much higher in the US than in Europe and seem to be proportional to the production statistics. Based upon a study by Mehran Alaee with the National Water Research Institute of Environment Canada the current PBDE levels in human breast milk in North America are 40 times higher than in Sweden. The issue is gaining public visibility after an article on the subject recently published in the New York Times.

SL It might be worthwhile checking the NPRI in Canada for information on Canadian use of PBDEs.

RH In the US, Great Lakes Chemical is the sole manufacturer of the commercial penta PBDE mixture. Note: they recently reported that less than 20% of the Penta & Octa demand in N. America is related to Canadian usage.

SL With respect to sludge management, what is the significance of the levels found in sludge and what are the pathways into the food chain?

RH This is the interesting part, looking at the bioavailability; potential uptake by plants and earthworms. The USEPA is looking at the effects of long-term exposure and toxicity in mammals.

SL Do you have hypothesis on a food chain link from land application of biosolids?

RH The question is more related to the health of the soil ecosystem and the wildlife connection. Benthic organisms would be expected to accumulate PBDEs. Plant uptake is probably relatively modest, similar to PCBs. There should be more concern about the exposure of grazing animals where pastures have been spread with biosolids, since pasture animals end up eating a fair amount of dirt. There have been limited blood samples collected from grazing animals. Analysis of these are pending.

SL Part of our project is to look at BMPs – do you have any insight based upon your work?

RH On paper, there is a route through soil to grazing animals, however, there is no data to back it up.

SL Using PCBs as a model for PBDEs, what is the most likely route of transmission into human breast milk?

RH Hypothetically it may be by consuming contaminated fish, as seen for PCBs in the Great Lakes area. A paper from Norway has documented this as a significant route for PBDEs, that is the fish being a reservoir of chemicals that are then consumed by humans.

SL Are the PBDEs getting into the fish because of sewage effluents or because of atmospheric deposition?

RH Background levels in fish are likely due to atmospheric deposition, but there have also been hotspots detected that would suggest a point source release. However the mechanism(s) of the release is uncertain. What is known is that sewage sludge is broadcast over fields and it is not always done perfectly. There is an identifiable signal related to inputs to sewage treatment plants and there is evidence of releases of low level PBDEs from sewage treatment plants and so it is a potential mechanism.

Analysis of biosolids shows a link to PBDEs from foam products. Seat cushion polyurethane foam can be 10 to 30 percent by weight PBDE. In a weathering experiment we found that the foam surface became brittle. As the foam degenerated, small amounts of dust were released that could eventually find their way into sludge. Granted not all foam is treated with fire retardants; it increases the cost of the product. But in some cases it is mandated by law -- for instance in some jurisdictions for material used in public buildings such as schools. Fire associations are pushing to expand the use of fire retardants and it is hard to argue banning them vs. loss to human life and property. Sweden is actively seeking alternative chemicals.

SL When looking at PBDEs in biosolids from across North America, do you see any patterns?

RH We expected to find more PBDEs in biosolids from municipalities with more industrial activity, but that wasn't the case, at least for the Penta- mixture. We also thought we would find more PBDEs in California where stricter flame retardancy requirements are mandated, but results to date do not show this. We are still collecting data.

SL The Ontario Ministry of Environment has undertaken a study of unregulated metals and has included PBDEs in the study.

RH We continue to be interested in results and samples from other jurisdictions to get a feel for the big picture. So far, European samples have shown very low levels. It is clear that we cannot simply stop spreading biosolids until we have it figured out. The major concern is with persistence, grazing animals, the high concentrations in fish. Not sure how it is getting out. Perhaps the spreading of sludge over a wide area is also resulting in surface volatilization.

Interview Transcript

Call To: Ellen Harrison, Cornell Waste Management Institute

Date: 13 February 2002 **Time:** 15:00

Taken By: Susan Liver (SL), Erik Apedaile (EA)

Reviewed by E. Harrison 11 March 02

EA provided an overview of the biosolids program in Ottawa and the approach for this project

EH Asked for a copy of the report resulting from the literature study.

EH NAS is doing a review in the US.

EA Can you provide an overview of the CWMI

EH Created in1987, started because State Legislature dealing with 'homeless garbage' issue. The State created Waste Management Institute at Cornell using money from a court settlement with an oil company in the 1970s. The decision was to place the institute in a centre for the environment at Cornell, so it is not associated with any single part of the University, which is made up of different colleges and schools. The Center "floats" under the Vice-Provost for Research so that it crosses all of the lines. CWMI has focused primarily on solid waste and not hazardous waste issues. CWMI operate with a very small staff and collaborates with faculty, students and others outside of the University. Try to get involved in applied research. We try to have a research and outreach component on all of our projects.

Worked on organic residuals projects for a number of years – trying to help municipalities divert yard waste – in part because organic residuals are a large part of the waste stream and in part because there is a good fit with agriculture, which is a strong component of the University. Began to get involved in sewage sludge issues in 1995, primarily drawn in by the agricultural side. Growers wanted to know if they should be using sewage sludge. Cornell had not been providing much advise on whether farmers should be using sludge. Universities do not speak with one voice and historically, before 1995, at Cornell there were contentious debates over sludge issues. There were engineers who felt land application is acceptable practice that they promoted. Other faculty from an agricultural perspective had a more cautionary approach. The engineer types moved away from Cornell by the time I became involved in the issue. We have been working with a group of faculty who tend to be more risk adverse. The involvement that the CWMI has had with the land application issue – I have been interested in issues of negotiation, mediation and dispute resolution apart from the sludge issue. CWMI was one of several stakeholders, including NYC, NY Department Environmental Protection and a number of other parties representing a number of points of view. Over a year and a half, with a hired negotiator, we tried to reach consensus about land application policies in New York. There were 45 different stakeholder groups. Came very close to consensus, but then it fell apart in the end. My sense that it fell apart because there is a significant difference in how people value risk and their view of technology, so it came down to most of the people who were generator and the regulators tended to have an engineering perspective, which tended to be mindset that technology can solve things. On the other side were people who were environmentalists, or from an environmental perspective who looked at where technology brought use – things like DDT and persistent organic chemicals that we were told were safe but are not. This is a simplification. Different ways at coming at the problem which made it hard to come to a consensus. It fell apart in the end over the issue where the concerned group could live with land application in the short run as long as regulations and measure are in place that will continue to improve the quality of the sludges and as long as research continues in areas where there are unknowns. The generators – usually municipalities, responded that there were other priorities for spending money and that sludge was clean enough. It was an insurmountable division at the end.

EA So nothing happened after that point?

EH It actually fueled the two different sides resulting in divergence and a fair amount of anger at the end of it. At the CWMI, my role has been trying to be a bridge between work done at the University and applying it in the real world.

EA So your role is primarily on of extension.

EH That is largely my role, although I also try to promote appropriate research and trying to facilitate people working together who otherwise wouldn't, i.e. between different disciplines on campus, or people on campus teaming up with farmers, municipalities or whoever else. My personal interest is not conducting detailed research, it is not what I am paid to do, but rather work with people like Murray (McBride) who are passionate researchers and help take their research to influence what people do.

EA It sounds like you have a big picture view.

EH I try to have, but am frustrated by my inability to come up with a good solution for sludge.

SL What was the time frame of the stakeholder consultation?

EH 18 months, in approximately 1995 to 1997. It was very intense – we did exercises to try to breakdown barriers. One of the things that really upset people was a series of publications that come out of extension that are recommendations t grown, for field crops, vegetables, fruit… Traditionally they dealt with [pesticides and fertilizers. In 1997 a group of us wrote a section on field crop recommendations in that publication with respect to land application of sewage sludges – it was a cautionary statement. It did not say don't do it, it simply said if you are going to do it, make sure get test results, apply clean sludges, more conservative soil values. I wrote the Case for Caution to provide the documentation as to why we had those recommendations. It has been interesting that at that point that Cornell was the only University or academic group that had put forward more cautionary stuff. Found that colleagues from other universities were under significant pressure not to raise issues, probably because they are state agencies. We actually received a threatening letter from the USEPA and I am very thankful for the support received from the Cornell administration.

EA Why from Cornell and not from other Universities.

EH I did find our colleagues receiving a significant amount of pressure. If you look at the literature, the best predictor of research outcome is who funded it. Much of the funding for sludge work is from the sludge industry or the EPA, although they are no longer putting money into research. There was a group at Penn State that put out a publication in 1985 called NE Guidelines for application of sludges, that had much more cautionary numbers particularly in regards to copper, nickel and zinc phytotoxicity issues. Dave Bolden, one of the authors is now at Cornell and is a co-author on Case for Caution. So, there was a group in the mid -1980s who were questioning. In terms of what has changes, the science of phytotoxicity has not changes. What has changes is who is funding the work as well as pressure tactics. I started getting nasty stuff from some researchers as well as from EPA – it was quite intimidating. David Lewis is a case in point – because he is providing expert testimony at a wrongful death suit, whether he is right or wrong, he is under phenomenal pressure – he has been threatened by Synagro in ways that are just awful, and most people don't have the stomach for it.

EA The main question that we would like to focus in on is, what in your opinion are the key areas of concern related to land applying sludge and public health.

EH In Ottawa have there been incidents where people have alleged health impacts from land application of class B (biosolids)?

EA Yes, there have been a couple of cases.

EH Have you seen the material Helene Shields has complied?

EA Yes

EH Helene is not a scientist, she has collected anecdotal information that people have submitted to her. However, as I look at this information, I am struck by the commonality of symptoms among people in different areas. I have come to believe that in some circumstances, sludge application has made people sick. I don't know if it actually responsible for killing people. I believe that the most acute need is to find out what is going on in those cases. At this point there has been no systematic, epidemiological investigation of any of these cases. The EPA delivered a paper to the NAS group, regarding an incident in Alabama that said that there is no evidence to link these illnesses to land application of sludge. I sat on the academy panel so I looked into it. I got an e-mail from the EPA that said that they did not investigate the health aspects - it is not EPA's role. It is appalling that there is no way to catalogue, to register complaints and there is no investigation. My sense is that it is probably airborne stuff. The Dowd paper was amazing, in the abstract, it says that if you live 6 miles away, there is no problem. Then you read the paper where it says that if you live within 100 meters, your chances are 50%. So maybe we shouldn't be surprised that people are getting sick.

The EPA, along with USDA has a relatively small project to look at bioaerosol and volatile emission issues. It is underway now and it is quite limited. What they have done is some chamber studies to look at what is volatilizing right off sludge sites. Then they plan to do some field sampling. There is skepticism among some e that EPA studies look to find a particular answer. On the other hand we did have a phone call with the researchers and some of the anti-sludge activists so that they could get an understanding what the experience of some of these people – so that they could set up a worst-case circumstance. I don't know the outcome – we have been trying to get the results from the first stage of the work but have so far been unsuccessful.

EA Is there any plans at Cornell to do some monitoring? Perhaps there should be some monitoring around some sites.

EH There is no monitoring that I am aware of. It seems to me that what there needs to be an immediate investigation launched, such as with a food borne disease outbreak, when there is a sludge incident. It is clear that there are a number of Class B sites that are not making people sick, at least we are not getting complaints for all sites. So randomly going out and monitoring sites may not be helpful. It is like the Ohio study, which was not a very useful study.

SL Why was the Ohio study not useful?

EH First, I think that more than half of the people dropped out of the study during the course of the study. The other thin, it was a single type of sludge, under Ohio conditions. It may not be relevant in Alabama, where I saw a video of sludge spread and then a very heavy rainfall that caused runoff from the field into a trailer park, where people lived. The investigation has to be where people are getting sick. We have to zero in and study where the people are experiencing the problems.

EA If the pathway is airborne, and you investigate after the fact, you may not be able to find anything.

EH Yes, it would be difficult, but in many cases it appears that the problems are persistent. In the case of Riverside CA, the air was already polluted. The people may have already been only marginally healthy, so the small addition of another irritant causes a problem.

SL The EPA is doing the study – who are the researchers?

EH John Walker from EPA and Pat Millner, a USDA pathogen research person.

EA Where is the study being done?

EH Still up in the air, probably close to their home base so it is convenient to them. They have not yet picked sites.

EA What is your opinion on the Class A vs. Class B debate?

EH I think that the acute problems are associated with Class B. As a Medical Officer, based upon the anecdotal stuff, I would be reluctant to say that application of Class B is an acceptable risk to the population. Until we know why in some places some people are getting sick, until we know what management practices will prevent it, we have to be cautions. With respect to Class A, my concern is ecological or agricultural – phytotoxicity issues, persistent accumulative toxics issues. They potentially have a health impact in two populations – if used in home gardens, I don't believe current EPA rules are protective of a home gardener. The dietary assumptions are very flawed – the uptake coefficients for things like Cd are based on geometric means, which does not make sense. Second I have concern for farm family that is using it. Sludge tends to accumulate lipophyllic organic contaminants. For example, 98% of dioxins that go into the STOP end up in the sludge. The same goes for other things like PBDE. If they are persistent, and you apply them in a way that exposes livestock, these contaminants can build up in the animal product. The average consumer likely does not get all of their milk from animals exposed to sludge, so exposure is not that significant. However, a diary farm family may be getting all of their milk from animals exposed to sludge, also exposed to airborne emissions and possibly contaminated water. A risk assessment of farm families is probably warranted.

EA Would you agree that if you are not spreading on pasture lands, the risk from the lipophyllics is better contained?

EH In terms of the transfer to food chain, yes. The EPA risk assessment suggested that soil ingestion was the most limiting highest risk pathway for 4 or 5 of the metals. That was a pathway with questionable assumptions. They assumed that only children ingest soil and that the soil was undiluted biosolids 356 days a year. The risk assessment based on soil ingestion should include ingestion after the first six years of life. Estimates for adults are in the order of 50 mg/day, based on limited information that did not include home gardeners. I have no confidence that the 50 mg is a real number. It is clear that that pathway should be reinvestigated – it was overly conservative in some parts and did not include people beyond 6 years of age.

EA Does this relate to a farm family?

EH The risk assessment simply relates to a child and does not specify where the person lives. I would say a farm family or a home gardener, people that are using the material as part of a land application scenario– they would be the ones that I am concerned about.

If you are saying, restrict it to class A, not put it on pasture, and not allow home distribution, the direct human health risk would be substantially reduced. I still might have concerns, but they would be much less.

EA Does the NYC sludge still go to Texas?

EH No, that has stopped. A fair amount of NYC sludge goes to an N-Viro facility in New Jersey, using lime to create a Class A product that is used as a liming soil amendment.

EA What types of products are coming out of other Municipal plants?

EH Syracuse has a major N-Viro Plant. There are a number of plants that are dewatering – typical Class B material. There is a certain amount of composting that is going on – it is not being used in agriculture – it is being used in parks or given away to households.

EA If you were in charge at EPA, would you throw out 503 and start again?

EH On the good news side, they have for the most part looked at appropriate exposure pathways. They missed completely on the airborne pathway. They did a little airborne work, mainly volatiles related to workers. I have wondered about the impact and implication of dewatering polymer on airborne emissions. There was work out of Delaware. Dewatering polymer is present in significant concentrations, and my understanding, not based on anything published, is that some of these polymers can release dimethyl amines in to the air – this is a huge gap in our knowledge, and the formulations are proprietary and often change.

The bad news is that they risk assessment is bad, and the attempt being made by EPA and industry to suggest that having done a risk assessment you now have the answer is disingenuous. You have to make many different assumptions and policy choices when you do a risk assessment so to say you have the answer is false. Parts of the assumptions are conservative and some are not, so I have objections to the assumptions that went into it and believe that there are better methodologies today such as a probabilistic approach.

EA Has the New York Dept of Environment set more restrictive rules for sludge application.

EH Yes it does, and they are in the process of being revised for the past 10 years are finally formally proposed. They have significantly more restrictive cumulative limits for contaminants like Cd, Cu, Zn and Ni. I'll send you a web site with the numbers. They have requirements for testing of sludge input materials for some organic contaminants. They used the 127 priority pollutants that are not terribly relevant to sludge, but at least they are trying to look at some of the organic contaminants.

EA Did it address application rates?

EH Basically agronomic rates. They do not have what Ontario has, which is a maximum application in 5 years, which is a good thing to have. It also says that material must be incorporated, but you can apply for a variance, so there is certainly application to pasture going on. This applies to Class B material. Class A material is really not regulated in the same fashion.

EA Do you have any ideas on BMPs?

EH I think that we have talked about some, such as the pasture issue. I don't think we have very good information on how to minimise airborne emissions. I presume that when you are tilling, depending on how dry it is, you are aerosolizing things. I don't think that we can get a handle on BMPs. Nobody has looked at all of the incidents to see if there have been any commonalities.

EA What is next for you?

EH I am looking forward to the NAS report getting done.

EA Will it be any good?

EH Yes, I think that you will find it interesting. It is not going to say people are or are not getting sick from sludge. The charge was to look at the adequacy of the risk assessment and how the pathogens were assessed and the adequacy of the rule with respect to pathogens.

EA Do you think it will be a driver for municipalities moving to Class A?

EH I don't know, I think the economics will be the driver. I have not seen the EPA make strides in that direction. I had being raising the issue of surfactants 4 years ago. There was a letter from the EPA saying they have reason to believe there will be trace levels, but until they see evidence that surfactants in the sludge in the field application has caused an environmental problem, they are not going to look at the issue.

EA You said that the EPA is not interested in the human health aspects.

EH No, that is not the case. The rules are set to protect human health.

EA The rules are set to protect the environment and health is secondary.

EH No, under the Clean Water Act the rules are supposed to be protect5ive of human health and the environment and most EPA rules address human health and environment is secondary. For example, they have come out with a draft for round 2 of the sludge rules. In the first round they had a process for selecting contaminants to regulate. On of the things they did was use data from the National Sewage Sludge Survey in 1988 – the detection limits were so high and they threw out anything that was not detected in at least 10 percent of the sludges. Under court order, they had to do a second round. Under that they have selected dioxins and furans for regulations. They have looked only at human health, not environmental health, and they have only looked at cancer risk.

The EPA regulations are based on health, but they do not have epidemiologists or health professionals to investigate disease outbreaks. If there is an outbreak, they call in the CDC. The CDC the agency that should be brought in to investigate these illnesses.

EA I was troubled by their HID 10, because it only addressed workers.

EH Because it was brought as a complaint by the mineworkers to NIOSH, so it was a NIOSH report that only investigated workers. The CDC has never being engaged to look at other issues. They only come in when they are requested to do so, and for some reason no State or Municipal health department has brought them in to look at the sludge issue.

EA In the Case for Caution, under suggestion for policies, you refer to a study by the Oakridge national Laboratory – what was the outcome?

EH They (EPA) promised different research, including an ecological assessment of round 1 contaminants. They contracted with the Oakridge National Laboratory, and the scope of the study was whittled down to a literature review and the EPA has never released the report.

EA Any final words of wisdom?

EH If it is possible to err on the side of caution, do it, put in place a system for complaints investigation, and not to continue with a 'head in the sand' approach that everything is all right. I look forward to seeing your report.

EA Thank you for your time and input.

Interview Transcript

Call To: Tony Ho, Ontario Ministry of the Environment

Date: 5 February 2002 **Time:** 09:31

Taken By: Susan Liver (SL), Erik Apedaile (EA)

Reviewed and revised by T. Ho 5 March 2002

EA provided the background for the project including using the WEAO review as a starting point. Highlighted the 3rd Party review component with Dr. Donald Cole from University of Toronto.

Tony expressed interest in being provided information regarding discussions with Dr. Cole.

TH Have you seen the NW Biosolids Association review of metals ? I gave a copy to Helen Ryan (all the TSE members were provided with a copy). It's a good report in 6 parts. There is a blurb on the unregulated metals. Talked more about abundance of these metals in the earth's crust. Not much on amount in biosolids.

TH Also a report to the EU Environmental Commission that came out in late 2001.

EA Yes, we have a copy of that. We also talked to Dr. Hale at VIMS about PBDEs.

TH We are planning to sample PBDEs. We started taking samples in December. We're monitoring non regulated metals over 12 mo, 25 plants, also samples from fields across S. Ontario (one time only). Some have rec'd biosolids, some manure, some nothing. Looking at both regulated and unregulated metals. I will email the list of things we are analysing for. We will be analyzing for tin and thallium at U of T G(don't have the equipment for this at MOE). We plan to calculate at what point any limits on the soil might be met. See if one particular metal governs the loading rate. Study will finish in May of this year. Report to be complete in December this year.

EA Do you anticipate regulations arising from this?

TH No, the report will simply give the profile of these metals, compare large and small plants, look at the soil ranges etc. The MOE will then use the report to decide if additional metals need to have limits, source control etc. This will be done internally at MOE/OMAFRA. Starting in December 2001, we will take 4 samples per plant for PBDEs, dioxins, furans and dioxin-like PCBs. There will be a second round of soil sampling in spring 2002 at may be half of the110 fields to collect samples for PBDE, dioxins, furans, dioxin-like PCBs.

EA Do you look at the breakdown of PBDEs

TH Yes, we will look at the different PBDEs. I need to confirm this with the lab. There are still a few things to go in place.

EA What will you do with the data

TH BDEs is a difficult issue. The question is whether the concern is related to biosolids or not (pathway). Looking at the concentration found in the soil will be important. We haven't decided for this or metals whether to take a risk-based approached or a "background based" approach as described in the MOE Contaminated Site Cleanup guidelines. The "background based" approach uses the say 95th percentile of the maximum measured in the soil As the limit for soil, then based on max allowable nitrogen or solids loading rate for biosolids and a minimum number of years for a field with average metal concentration to reach the max soil limit, then a max allowable metal concentration in the biosolids can be set. For organics we can look at the degradation rates. From all of this we go back and derive a limit for biosolids. (SL note: this is discussion is unclear – needs to be clarified). If Mo is the limiting element, then the concentration of dioxins is less important.

If biosolids are a significant contributor to BDEs in the environment versus air, water, other. This needs to be a lot more long-term issue.

EA The limiting element may be different in Ottawa versus Toronto.

TH Agreed. We're looking at this from a provincial basis. There will be soils limits, biosolids limits, monitoring. But this is all very early stages yet. First step is to look at the data. We'll see which metals we need to concentrate on.

EA Can we talk about the Dowd paper ?

TH I spoke with Gerba. Not so much the methodology for the risk assessment but the method of land application. I believe the work done by Dowd was based on Sierra Blanca, TX. The 2001 paper didn't really present the data but referred to two earlier papers. There were 2 groups of professors in TX and AZ.

The main thing in my discussions with Gerba is that the biosolids were shipped from NYC as dewatered, this was stockpiled in the field. This was the point source of moving the piles around. The other thing which surprised me was that they spray irrigated the biosolids up to 50 feet in the air. They liquified it. It's unclear if this is the standard practice. This may be an easy way for them to do irrigation and apply biosolids at the same side. I have not been able to get written confirmation on this. It was apparently an oversight that they did not mention this.

The other thing he mentioned is that other work he did afterwards in AZ. They did broadcast application but they couldn't find any pathogen several feet or several tens of feet from the application point or application site.

EA The '96/'97 work showed that there wasn't much in the way of pathogens

TH I recall one of the papers had very low plate counts. I sent an email to Pillai asking how this was reconciled with the rates. He replied that they resampled with a different methods and found more organisms. The method of application needs to be confirmed. (Tony to send email).

TH I haven't been able to locate Dowd. I spoke with Gerba about site broadcast with chains to incorporate, but they haven't been able to find much. Call Gerba and Pillai. Pillai is involved on the panel of NAS for the risk assessment.

EA What MOE programs are currently underway related to biosolids management in Ontario ?

TH The ministry has announced the Nutrient Mgt Act will be passed. We hope it will be passed this year. Under the Act there will be regulations to control nutrients ranging from commercial fertilizer to biosolids and manure. Everything is being looked at. We're really at the early stage. The information will be coming out shortly … this year. There will be consultation at some stage. Too early to tell if there will be minor or major changes to the current guidelines. There will be a continuous improvement process.

We are working also on the EMS demonstration project which we see as a key piece. Even if the guidelines are adequate, there needs to be trust in the compliance and enforcement. We feel the EMS will be an important component of ensuring and going beyond compliance. Obviously there will always be enforcement. We want to see how EMS can compliment enforcement. The second stage will consider going through to 3rd party certification.

The other work is how to manage pathogens in material. For example, do we need to create "Class A" material or better? Or can we manage the pathogens to prevent them from entering the surface or groundwater allowing the pathogens to die off naturally in the soil. In talking to a number of people including Susan Springthorpe at U of O, it seems that if we do not have macropores in the soil, it's reasonable to expect the pathogens will stay in the soil and the top 5 cm.

Studies were done by CCIW with a lysimeter at much higher loading rates than we use over a 3 year period. They did not find pathogens moving through the soil. They found most of the coliforms remained in the soil column.

If you look at the current separation distances for a septic system tile field [from a well], where the soil has been disturbed versus a field that has macropores… In tile drained fields liquid manure has been shown to run in the tiles in 15 minutes after application. Bacteria were detectable in tile drain water from fields applied with liquid manure has even shown up, up to 3 weeks later.

EA Over 90% of the fields in the Ottawa area are tile drained. They can act as a short circuit for liquid movement to the surface water instead of the groundwater. But this is likely different for solid biosolids

TH We can't guarantee that the macropores don't play a role with solid biosolids. It may depends on how soon and hard the rain will occur etc.

EA Pathogens will likely be attached to solids in the biosolids. With a dewatered cake, the solids will not easily move downwards, even with macropores.

TH With the liquid manure study, 3 weeks later with a rainfall (when the pathogens should be attached to the soil), they are showing up.

EA The chunks of biosolids stay together. Also, according to literature, the travel distance of bacteria is only 15 to 30 m in saturated conditions.

TH The problem we are facing with the public is that we don't have a lot of data to demonstrate this. We thought with the liquid manure that it should have been attached. Working with OMAFRA on this. We need to look at the tile drain, pre-tillage and incorporation., How do we treat solids versus liquid. What if we restrict the rate of liquids vs solid ? Lots of folks coming to a consensus – U of New Hampshire looking at clostridium as a potential second surrogate indicator than e coli or fecal coliform…

We need to put together a lab and field work combination to assure the public.

We're putting a workshop together on Feb 13 including Cities and research people to discuss what work needs to be done to assure ourselves and the public. This will not be done overnight, but we want to get a start on it.

SL What do see as impact of Walkerton Part II on biosolids management?

TH I don't know. The NMA will likely be part of this.

EA Do you see the role of BUC changing?

TH I don't know. The committee itself is going through some soul searching. You should talk to Janice Patterson or Randy Jackiw.

EA Anything from NAS ?

TH All I have heard is that it will come out as scheduled – late spring, early summer. Everything under wraps. Lots of people watching this.

EA Any general comments on BMPs

TH No, I'd get comments from OMAFRA collegues.

TH Please send papers on 30 m pathogen travel reference.

Interview Transcript

Call To: Dr. David Lewis, University of Georgia

Date: 19 February 2002 **Time:** 09:30

Taken By: Susan Liver (SL), Erik Apedaile (EA)

EA provided an overview of the biosolids program in Ottawa and the approach for this project

EA The paper that you sent to us is the first thing that we have seen where human health effects from land application of biosolids have been documented.

DL I was happy with the outcome of the work – we felt we had a decent handle on what is happening when people experience and what we have to look at. It is a common sense sort of thing; there is nothing mysterious – if people were claiming that they were getting multiple sclerosis or Alzheimer's from sludge it would be different. We found the kind of things that you would expect to happen – people living next to where lime stabilized material is blowing in their direction, they are getting burning eyes and burning lungs – you wouldn't really expect anything different. I think that the only thing really surprising in the work is that the rate of staphylococcus infection is a lot higher than I would have thought. I had thought that we might occasionally turn up rates of staphylococcus infections that would be similar to rates in a hospital.

EA We would like to go through some of the specific details in the paper. Can we look at the data on a site-by-site basis? Was there a range in the sites, were some sites worse than other sites?

DL At virtually all of the sites there were several symptoms that most everybody complained about, like burning eyes, coughing and congestion. Beyond that there were insufficient data to conclude whether there is much else going on other than the staphylococci infections. 48 people and 9 sites were barely enough to just get an indication of what some of the biggest problems may be. To really look at the situation and to conclude something beyond what we did, we would have to look at hundreds of people. In order to get a handle on things that are still important like rashes that would show up occasionally, that is an important issue that should be tied down as to whether it is associated with enteric viruses or associated with traces of nickel and chromium, where people are sensitive to nickel and cr. Some of these issues are important, but we could not address them.

SL How did you select the nine sites, and was there lime stabilization at all of them?

DL I think that there was lime stabilization at all of them. Basically we checked with county health officials and got whatever records we could that way. BLANK. We did not use any list of "victims" provided by environmental groups to generate subjects for the study. 52 individuals were interviewed and that looked at Helene Sheilds, who kept a list of people that she had contacted.

SL It is quite broad ranging to go from PA to CA and Ont. Was it essentially speaking with people from the counties who put you onto the cases?

DL My understanding is that once a person was identified at a particular site who had complained to the county officials, we would ask that individual from name of neighbors who had also experienced certain problems, who would then be contacted. The objective is not to establish some group of control, unexposed people and exposed people. It was important to get an idea of what sort of complaints people are registering out there; are they gastrointestinal problems, respiratory problems, or are they complaining about Alzheimer, cancer and MS.

SL Was it a coincidence that all of the sites had lime involved, or did you select for that.

DL That was coincidental and what we did find out in Riverside CA, there was a number of residents that, when we checked the county record against where these people lived, it turned out that animal wastes had been applied in one or two cases and their symptoms were indistinguishable from people complaining where lime stabilized class b biosolids had been applied. According to County records animal waste from dairy farms had been applied, and the animal waste had not been treated with lime. However there were a couple of complicating factors that I have been trying to get a handle on. First, the soils in that part of CA are very alkaline, so people would not surprisingly be complaining about burning eyes and lungs just by breathing natural sand. The other think was that one of the resident in the area had a contracting business that had a subcontract with a dairy operation and according to an employee of the dairy operation, Class B Biosolids were being mixed with the dairy waste, so it was not simply dairy waste that was being applied. I tried to pursue this with the County and they were not inclined to investigate whether or not this was occurring. I was not able to clarify this to find out if we are dealing with the same sorts of problems with animal wastes, as we are experiencing with biosolids.

SL Why would they take the trouble to mix the two together?

DL What would happen in the area is that every time citizens in the area would complain about adverse health effects from the sewage sludge, the company applying sewage sludge would say that it was not sewage sludge, rather animal waste that we being applied in that area. It turned out that it was very difficult to track where biosolids were being applied and where animal wastes were being applied.

EA The cases that you have in your paper, how was the sludge applied?

DL The material is stockpiled and then at some point spread out on the land. It was not tilled into the land, and there were not crops grown on the land over the period of application. It was really just being used as a disposal site. One of the problems wee have in the US, such as in CA, farmers can make $20/ year, over the cost of leasing land, so large tracts of land can get purchased and be used profitably as land application sites, and you don't grow any crops on it.

EA So after 7 years had passed, then the topsoil was mostly lime-stabilized biosolids.

DL Yes. In the case in almost every one of the sites in the US – the material was just spread out on the surface and it just dries out.

EA So, how did staphylococcus survive in this alkaline material for so long?

DL Staphylococcus in soils where animal become infective, it can remain for several in the soil. When sludge is mixed with sewage sludge, on assumes it permeates everything in the sludge and raises the pH. However, it becomes obvious in situations like that, you get microenvironments where all the particulates in the material where the pH may be neutral or acid, even though the overall pH is alkaline. You see that whenever environmental changes occur, whether it be in soil, sludge or sediments at the bottom of a river, once conditions become conducive for growth of a particular organism that has a certain oxygen or nutrient requirement this material becomes a source of a bloom of these types of organisms. It tells you that these types of organisms are there; they are just embedded in these microenvironments, where the pH, the oxygen concentration and the nutrients are quite different than what they are in the bulk material.

EA How do they bloom outside of the microenvironment?

DL What happens naturally, if you look at seasonal algal blooms in rivers, swamps, streams, ponds and lakes, what happens is that there is a seasonal succession on these organisms that involves actinomycetes bacteria and certain blue green algae and so forth that is associate=d with seasonal changes ion weather. There are physical changes in the environment that initiate microbial populations to where organisms that are just quiescent in these microenvironments get churned up. To bring it back to agriculture, you lime the sludge and incorporate it in soil, there is a large number of staphylococcus that are embedded in those particulates that are there quiescently and are not going to cause a problem until a windstorm blows the dust from the field into some other environment where they are exposed to environmental conditions that a re different to what they were in the field in the soil. The dust becomes a source for inoculating these other environments. When the dust blows from the field into somebody's house and settles on their bed sheets or the kitchen counter and they prepare some food, the microenvironments become a source of low levels of pathogens that were in the original sludge and they just bloom out. My concern is that, particularly with lime stabilized material, you have created a different animal. In the world of infectious diseases, we normally operate with things like flue viruses that get on doorknobs, and people handle the doorknobs and then they rub their eyes. That is the main sort of mechanism of transmission. We are dealing with organisms that are in and on surfaces that are in and of themselves inert with regard to transmission of disease – they just become physical sources of contact. What happens with processing sewage waste are two things. First, you take the material that is very rich in microbial biomass. Most of that biomass is gram-negative organism. When you kill gram-negative organisms, you liberate endotoxins. So the process of taking large quantities of gram negative biomass and treat it in such a way to break it down into a crude preparation of endotoxins. We have added lime to the sludge to kill the organisms, so we end up with a mixture of endotoxins and lime, two things that are going to cause eye irritation, respiratory tract irritation. The endotoxins are going to generate even GI irritation. So what we have created a material by design that will break down our primary defenses to infection. We rely on the microcillia in our lungs to move out this thin film of fluids where viral particles and bacteria make their way into the lungs when we inhale dust – vital to an individual's resistance to infection. We also have healthy skin normally. If you add a contact irritant – lime and a good mixture of endotoxins, you can get rashes on the skin and have created another portal of entry for microorganisms. You have essentially assaulted another essential defense mechanism against infection. The way I look at this is that we have a pathogen chemical problem. It is not just a pathogen problem and it is not just a chemical problem. I will have to be approached from a public health sense completely differently from how we approach pathogens or chemicals by themselves.

We have basically created little soil particles that are embedded with endotoxins and in this case lime. When this particle, which is bearing low concentrations of reparatory pathogens and bacteria and viruses that cause skin and GI infections – we have embedded these pathogens in an envelope that breaks down our resistance to infection.

SL Isn't lime stabilization recognized as one of the class processes?

DL Yes it is. This leads me to my other argument. Even if we get rid of all the pathogens and move from class A to class B, we may still have an infection control problem.

SL The example where you talk about 132 metric tones of biosolids with 12 tonnes of lime – that ratio seems to be too low to qualify as class A. Was this typical, where some lime was added, but it was not sufficient to call it class A, where you get the required kill of organisms?

DL They are only adding enough lime to raise the pH above 12 for the proscribed amount time and they don't add any more than that because of cost. It is typical to find limed material that is nowhere near 50/50 ratio.

SL Where was the site you mentioned in your paper that was located in Ontario and was it spread with limed material?

DL I recall there were a couple of contacts in a Town called Cedarville.

EA How was the pathology of the symptom documented?

DL Mark had a questionnaire. He first asked the individual to narrate what their problems were. He then went down a checklist of symptoms that were compiled from Schiffman article with USDA on symptoms that have been self-reported. He also used the 1985 study that had symptoms that they looked for. We then complied a questionnaire of symptoms that had been reported or expected associated with exposure to sewage sludge. When there was an affirmative answer to a symptom, then the individual would be asked whether they could recall the occurrence of the symptom relative to their exposure to biosolids – whether it was an immediate reaction or something that developed days weeks or months later. This information was compiled, and a chi-squared t4est was applied to the data to see if there were any symptoms that occurred independent of site. We would expect variation based upon peoples age, type of sludge and so forth. In cases where there were individuals who sought medical attention, we requested copies of medical records. In most cases of staphylococcus, we were able to get copies of medical records. We were able to get medical records of the three people who actually died.

EA Of the 48 people referred to in your paper, what proportion would have sought medical help for their condition.

DL I would guess about half of them. In NH for example, most of the residents complained of various problems that were consistent with the conditions we reported in the paper and most of the m sought medical attention from one particular doctor. In PA, with the staphylococcus infections, medical attention was sought by probably 80% of the people who had infections.

The particulars in the Cedarville case, the info was collected on 4 April 2001, resident living 500 feet from a treated field, spread with Class B Toronto sludge applied in solid form by Azurix Terratec. The time period over which symptoms occurred was Aug 31 2000.

EA Do you have information on when the sludge was applied?

DL People who witnessed the dumping complained of irritated eyes and breathing. There was indication of a test on a well after dumping that indicated *E. coli* contamination.

EA Was there record of staphylococcus infections in this case?

DL No, the symptoms that this individual reported was burning eyes, throat and lungs.

EA Was there indication of the length of time that the symptoms persisted for?

DL The symptoms developed immediately after exposure and lasted for approximately 8 hours.

On all of the questions about infections, they were negative. The individual did not recall any infections.

SL I would like to ask you some questions about the ISC3 modeling and how you converted that to exposure time. You modeled this as a source in the field and I am assuming that you looked at wind direction and speed and then you did a percentage dilution at household C.

DL That is correct.

SL When you came up with the exposure numbers, how did you define exposure. What percentage of the source was the threshold to say that somebody was exposed?

DL We used the air dispersion model combined with the wind plot model that gives you a pie chart of wind direction, speed and frequency. From the pie chart you can get the information of what percentage of time during a day did the wind blow in a certain direction. We had the area surveyed and we knew the window of direction from the field to household C for example. With the wind plot data we could take a segment of window time that we were interested in, in this case the time when symptoms were being experienced. We could figure out how much time wind was blowing from the field to the house. We could add up how much time the wind was blowing from the field in that direction and that was the exposure time.

SL So the exposure time was any time the wind was blowing towards the house. You have calculated a relative gas concentration, saying for example if there is a gas concentration of 100 over the field and if the wind is blowing at 10 km/h towards the house, my concentration at the house is going to be say 20% of the concentration over the field, whereas if the wind is blowing harder, the concentration is going to be say 30% of the concentration over the field.

DL The ISC3 model does all of those kinds of calculations and I don't have a feel for the details of the model. I was curious myself what is the relationship between wind speed and concentration of the gas at the target site. I would assume that at some point, the concentration would go up with wind speed to some point where it would then start to decrease from dilution.

SL Taking this information to define exposure, it's any time the wind is blowing in that direction, not above a threshold.

DL Yes. The point of doing this type of work was really to take a first stab at looking at how we can begin to assess exposure in a situation like this. The recommendation is that modelers can start from where we left off and polish our approach. From the work we have done, we are primarily dealing with an air pollution problem, transport of pathogens with dust, and perhaps a problem where trimethyl amine and ammonia may be an aggravating factor. The bottom line of all of our work is this. The USEPA is taking the approach that Class B biosolids can be applied without any restrictions. So if you want to set up a class B biosolids site right next to a retirement home, that's fine. The way their health will be protected is to identify the pathogens in sludge and go through the literature to determine the minimum infective dose for these organisms. We will then eventually require monitoring of the pathogen and make sure that levels in sludge are below that level. In our paper, we say that that is not a good approach. It is only going to keep the issue buried in controversy, because there is no agreement on minimum infective dose for these organisms. It is always going to vary based upon geographic area, the susceptibility of the population and so forth. So what we are saying is look at this problem as a pathogen/chemical exposure. You have created irritant chemicals mixed with low levels of pathogens. Lets assume that we are never going to sterilize this material to where you have gotten rid of all those pathogens. You are basically exposing people to irritant chemicals that are primarily going to be inhaled by people in dust and it is going to settle out on peoples skin and cause skin problems. We have to deal with it from the point where you start to restrict exposure, not try to regulate some chemical based upon whether the material is significantly infective. Assume that it is and begin to restrict exposure. Do a combination of air sampling looking at the levels of particulates that a land application site is generating. Use air modeling to ascertain the level of exposure of surrounding communities to that source and deal with it from that aspect where you begin to place restriction on the practice where you don't expose people and communities to particulates in biosolids. Our paper is a very crude first stab at how you do that sort of thing.

EA I have been doing reading on the epidemiology of sewage biosolids and this is the first paper that I have seen where somebody has gone out and documented people getting sick. Most of the epidemiology has been done on sewage plant workers and the results are that they do not have a significant increase in illness over control populations. The study in Ohio also concluded that other than a few factors there were not significant differences between exposed and unexposed individuals. It seems that in most cases, whether a person get sick or not depends upon the number of organisms a person is exposed to and their susceptibility. It seems that in most cases, if people are being infected, they are not exhibiting infections, the infections are sub clinical. Do you think that this type of exposure is significant?

DL Not in the short term. I think that from what we saw on the sites we looked at in the US, where we had at least a handful of individuals that we interviewed at those sites, there seemed to be a large proportion of people living in those residential areas were significantly impacted by the sludge operation. In contrast to the studies on worker exposure, there is a good reason for their results. In the worker situation, their primary exposure route is hand to mouth. They handle the material without gloves, they eat a sandwich and they end up gastrointestinal infection in the worst-case scenario. What has happened is the industry and the EPA in the US has extrapolated that experience to the sort of problems that we experience in this paper, and in no way can that jump be made. The kinds of problems that we saw are primarily respiratory and associated with dry dust. This is a totally different exposure route, and in the world of infectious diseases, that makes all the difference in the world. When you deal with the inhalation route of exposure you are in for some surprises because respiratory diseases that occur from breathing particulates contaminated with even very low numbers of organisms, when you expose the general population, you are going to infect a lot people that you did not expect to. You cannot extrapolate workers handling sewage sludge to people breathing living in residential communities the dry dust that comes from sludge operations. Even from an engineering standpoint, I would have thought that would have become apparent. If you look at Dowd’s work, for example where they modeled a worst-case scenario of sludge exposure. They looked at pathogens associated with sludge in a land application situation. They decided that the worst case scenario is going to be the worker standing out there when liquid sludge is being sprayed on these fields and he is going to be breathing these droplets of water that have pathogens in them. Their whole study revolves around that being the worst-case scenario. I would argue that that is by no means the worst case scenario, that when that water droplet dries out and what is left is a soil particle with the pathogens attached d to it, the lime that was in the liquid that was being sprayed is inn a far higher concentration than was in the liquid spray, by a factor of thousands. The same goes for pathogens. They are going to be in far higher concentrations on that soil particle than they were in the water droplet. Just by virtue of the fact that you have removed the water. With dust coming from land application site you are dealing with much higher concentrations of irritant chemicals and pathogens. So your worst-case scenario is not going to be the worker standing beside the field, but the person living in the house next to the field that has dust settle in their house day in and day out. I think that you have to look at this problem from a public health perspective from that standpoint, not trying to extrapolate the worker exposure, which I would argue is a far less hazardous material.

EA Do you have any comments on the Ohio study.

DL Not other than what they put in their abstract which was a caution about not extrapolation that to other situations. They dealt with a very low application rate compared to other parts of the US. It is hard for me to critique this study, because they don't even tell you what type of material was spread, they don't tell you how many people dropped out of the study after the first year. I have heard that the attrition rate was enormous. Other than that I don't have the information needed to critique that study. I think that they were wise to caution against extrapolation.

EA What type of advice would you have for municipalities spreading class B biosolids?

DL I though t that Riverside CA is a good model. The epidemiologist who wrote the County ordinances, decided that based upon the information available, they were going to impose a 2-mile buffer zone, which essentially precluded land application of Class B biosolids, as the population was quite dense. The industry complained that they were essentially banning spreading Class B biosolids. I don't think that they should be spreading Class B biosolids in heavily populated areas in the first place. The USEPA recognizes in the 503-sludge rule that for at least the first 30 days this material is hazardous for direct contact, so why apply it in heavy residential areas in the first place. So, for Ontario, perhaps a 2-mile buffer zone is not unreasonable for the time being, as it will push these operations away from populated areas.

EA How do you define a residential area?

DL Where people have their homes, where for example in NH, there were 8 to 10 houses on a street abutting the field being spread. Where you draw the line I don't know. Perhaps it should be up to individual communities to deal with. In Riverside CA, you have many thousands of people living right intermingled in 5000 acres of fields that are being treated with Class B material in an arid system where it just dries out and blows with the sand into all of their houses.

EA I wonder than if there is any sort of agricultural management of those fields that would be acceptable from a public health standpoint.

DL In CA they did have that capability, but it did not appear to me that they were doing it. What I saw when I was out there was bare fields, and I found myself gasping for breathe and we did not smell anything, there was dust blowing around – it was like a desert. The impact on breathing was very dramatic and very quick. If you were upwind of Riverside County there was no problem.

EA Do you have any advise on how we should proceed with investigating health complaints from biosolids?

DL First some sort of assessment needs to be done. There are ways of ruling out problems as a first cut. If a land application operation wants to set up somewhere, some sort of assessment has to be made of what level of air contaminants are the community going to be exposed to from the site. As a first cut communities that have the potential to be impacted should be identified, and residents should be made aware that the operation is being established and if you experience any of the following complaints, report them. In the US, people did not know why they were getting sick, and only later did they find out what they were being exposed to. They should be notified to look out for and who to report it to and if certain symptoms and if they occur, they should report it. Management practices can be put into place that protects communities.

EA Of then nine sites that you looked at, did you collect any socio-economic data on the people living there?

DL What came out from the EPA's office of the Inspector General assessment of these problems is that one reason we may not be hearing about more problems than we are hearing about is because the material is being applied in low socio-economic areas, where the people do not have the resources or the education or any of the normal things that cause problems to be brought to people's attention. For example, I received an e-mail from an attorney from Porto Rico; across the board the sludge is being dumped in the back yards of poor people who have no resources to do anything about it. The USEPA IG concluded that there is no monitoring of this problem in the US and that by and large this process is being put in the back door of lower socio-economic status communities. As IG pointed out, every time material is dumped near an upper class neighborhood, those individuals who are well connected see that the process is stopped.

EA Thank-you for you time.

DL One last not, ES7T invited me to submit a feature article that discuss much of whet we have discussed over the past hour. I expect that it will be cleared by EPA for publication in the next couple of weeks and then I can provide you an internal copy.

Interview Transcript

Call To: Dr. Murray McBride, Cornell University **Time:** 02:34 pm

Phone No.: (607) 255-1728 **Date:** February 11, 2002

Call From: Erik Apedaile (EA), Susan Liver (SL)

Message Taken By: Susan Liver

Subject: Pathogens

EA provided an overview of the project.

MM – I noted in the WEAO biosolids report the discussion of Ag, Sn, Sb, Tl. I saw data from Mel Webber on levels in Ontario. The range included high numbers. For example, the highest no. for Sn was 345ppm … I view this to be pretty high. I believe the data is older, maybe 1995.

Our initial point [in the Case for Caution] was to point out that the permitted loading of metals can be significant, e.g. at 200 kg Zn/ha provides 1400 ppm Zn above the stuff that is already there. We also have a problem with the concept of a "lifetime" for soil. Practices should be sustainable.

We're looking for phytotoxicity in crops -- Zn, Cu, Ni toxicity in particular. We've been looking at sites with high metals levels.

EA Around here we see Cu deficiency in the soil. What symptoms are you seeing ?

MM With Zn toxicity you see stunting of the plant and an induced Fe deficiency. As Cu and Zn increase, Fe and Mn reduce. Chlorosis is induced. We looked at soy, alfalfa, beans, peas.

Some sites are designed for long-term application of biosolids. Other are more dump sites … 10-20% of the soil weight is biosolids.

EA What happens to the sludge from NYC ?

MM NYC sludge used to go to TX but the contract has expired. They won't permit biosolids application in the watershed for the city (Hudson and Catskills).

Our work is mostly dealing with sludge from smaller cities. Syracuse, Binghamton.

EA How is it managed ?

MM Syracuse biosolids is now lime stabilized with CaO and used on dairy farms in upstate NY as a lime, not as a fertilizer.

EA Can you review your recommendations re: agreements with farmers ?

MM Farmer used to get the limed material and do with it as they pleased. Now the Enviro company does the spreading and controls it. The farmer used to let the stuff sit the field for months and years. It gets odourous, develops a crust. Goes anaerobic. Have heard from colleagues in NH that lime stabilization doesn't 100% kill microbes.

New York DEP is strict in providing permits but don't have the personnel to enforce.

EA Is the sludge mostly lime stabilized?

MM That's pretty well all we have to look at

EA Does the lime keep the metals in the soil?

MM Contrary to common conception, we find some metals are mobilized at high pH: Cu, Mo, Ni. Zn, Cd, Pb are immobilized. The result is that we've decided to look closely at Mo. Mo has the highest potential for uptake into forage crops.

In upstate NY, 70% of farming is dairy so majority of crops are for forage. Most cash croppers don't want to mess with biosolids. Dairy farmers have the equipment to deal with liquid sludge. Cash croppers don't have the equipment.

EA In Ontario it's the contractor always spreading.

MM In some cases the farmer is the contractor and contracts with a number of small STPs. In a particular case I know, it all ends up on the farm he co-owns. He's the contractor for waste handling. In many cases the farmer is the contractor.

EA What's your opinion of spreading on pastureland?

MM I don't like it. I think you put degree of risk on a scale for different kinds of crops. Surface spreading on pastureland is on top. No dilution. Whatever soil the animal ingests is going to be biosolids. They eat up to 1 kg/d. Now you have a direct conduit for toxins we don't know anything about going into fat. e,g PDBEs, dioxins, PCBs, and other stuff. Triclosan is an antibacterial being put in all kinds of soaps, detergents, toothpaste (Colgate Total for example). It's a chlorinated pesticide being used on the presumption that it's safe. Just about all of the chlorinated compounds will biomagnify.

On the other hand, you can used biosolids to fertilize corn for grain. Grain for animal feed seems relatively safe. Why would you permit pasture spreading?

On the metals side we've looked at forages with respect to metals uptake. We haven't seen much evidence for concern in the short term. Except for Mo.

EA I thought you had to have fairly acid soils and that you get Al or Fe toxicity as a result.

MM If pH < 5 then Al or Mn toxicity can occur in the case of uncontaminated soil. But if the soil is contaminated then at pH 5.5 mg/kg Zn can cause toxicity. You need to maintain a pH of 6 or higher. I recommend 6.5 or 7.

We worked on some sites in S. Ontario. We didn't realize the soils are so high in pH relative to other regions, eg. Adirondaks are acidic soils.

EA Around here, a lot is parent material on limestone. For the most part the pH is comfortably in the 6s

MM Crossing at 1000 Islands you go through granitic bedrock which is likely acidic soils.

EA In the Ottawa area, farmers lime to keep the pH at 6.5 in order to improve nutrient uptake.

MM Now sewage sludges much lower in Zn and Cd than 20 years ago. We don't see smoking guns [phytotoxicity] from agronomic application of sludges. Usually there is no more than a few applications on one site. In Ontario can only apply every 5 years so typically there is only data from 1st application so you can't see any affect to speak of because the loading is so low.

EA Source controls have reduced metals.

MM Ah, but is there any evidence unregulated metals go down with regulated metals? The one analysis that bothers me is thallium (Tl) which was reported for Ottawa as 131ppm. I have some doubts that it's real. It is possible the analytical method had a problem. We never see this. It would be a problem if it is real.

It's more toxic than Cd. It's more of an acute toxin. Cd builds up over decades. It's rather immediately toxic and will flush out of the system.

EA What exposure routes are there for Tl ?

MM In other parts of the world it's occurred via gardens or subsistence farming. People downwind of a cement kiln in Germany had airborne exposure. Behaves like K, taken up by plants.

Also in China industrial activity resulted in Tl in cabbage.

EA Is it immobile at pH 6.5?

MM It would be taken up. Tl is pretty available across the pH range. If you have a lot of clay it won't leach but it's likely to be taken up in fairly large amounts. Plant can't tell the difference between K and Tl.

You can apply more K to counteract. An antidote for the poison. It was used as a rat poison for many years until enough children died from eating thallium sulphate.

Why would Tl show up in Ottawa ? My PhD student summarized what it is used for: up until the 70's was for rodenticides. High Tech industry has found Tl additive to increase the endurance of alloys, increase photocells, semiconductors, and has interesting optical properties.

Most of these you would think are pretty small volume.

EA Where does it go in the plant ?

MM For some metals there is a barrier against getting in the grain but not for Tl.

It's very common for Tl not to be on an ICP scan even if 20-30 metals. The problem for this element is that the best line to use has an interference from another element.

It's possible that the data is compromised. The high number for Ottawa could be incorrect. For example, Tl in Great Britain ranges from 2 – 5 ppm.

We can certainly run analyses here.

EA The city has an ICP and a chemist.

MM Just warn him about the interferences.

EA We can start by looking at the existing data. What about other metals ?

MM For silver (Ag) General consensus is solubility is low. It's true Ag is not soluble. Ag sorption in soil is very strong. However, even at ppb levels Ag is a biocide. It will kill microbes. Someone calculated 1 ion will kill a microbe. My concern is not for human health but for soil health. The question is weather there is enough solubility of this form of silver to cause an effect.

EA Have you been studying soil microbes ?

MM We don't have a microbiologist. We've looked at earthworms. They aren't there (whether they don't go there or die). But people in the UK show that metals concentrations far lower than ours have an effect on soil microbes. There could be an effect on rhizobia. I dug up a plant and saw nodules. That means they are there, but is it enough? We don't know if the metal effect is direct phytotoxicity or indirect via rhizobia.

EA Did you have control sites to compare ?

MM In one area on edge of Cornell campus, one with biosolids and one without. However both sites are within an orchard and have some Pb and As contamination. I've got evidence of difference in yield some 20 years later.

EA Could other factors have caused the yield difference?

MM The soil where the sludge was applied 20 years ago has much better structure. This site was to test EPA limits. The application rates have no relevance for Canadian or Ontario limits. We're guessing what the application rates were based on Cr in the soil as a marker.

In these long term sites there is relative loss of some metals relative to others in the topsoil. Relative to Cr you lose Zn, Cu and some Cd. Mo is fairly mobile. We don't know where it went. 70-80% isn't there. We've gone down 60cms. When you get into the subsoil the metals concentrations drop to virtually background.

I agree 8 dry tonnes per ha is too little to affect organic content. Benefit from soil conditioning is miniscule.

We've been looking at preferential flow paths. When pathogens or pollutants move out of the top soil there is little trapping. Most of the subsoil matrix never even sees the metals. That's not to say it's deeper than we can test.

EA I would have thought fewer preferential flow paths once you get into the sub-soil.

MM Some have seen earthworms going down meters. Photos show at least a couple of meters of flow paths. Studies have put dye on the surface then created an artificial rain. Then they dug with backhoe. As quickly as they could dig the dye was already down there. This work by T. Steenhuis has been done out of Biological and Environmental Engineering dept.

The other three elements are Be, Bo, Cr.

Beryllium is very toxic but I haven't seen a single sewage sludge that looks like it has significant Be levels. It would need to be a very specialized industry. Didn't find it in test sites.

Boron: we raised this because it's very phytotoxic to some crops, particularly corn. There have been some horror stories with Bo. I'm not sure how that happens since it should more likely stay in the liquid phase. Borate salts tend to be pretty soluble. Specific types of glasses (like borosilicate glasses) that if the manufacturers release this to the STP there is a risk. Even the 1988 EPA study only showed 5-10% of sites with Bo in the biosolids.

A fertilizer company convinced a farmer to add 0.5 kg/h and accidentally applied 5 kg/ha. That was enough to stunt corn and cause burning on leaves.

Chromium: in the U.S. Cr is not even regulated. I'm not sure what to do with this.

The new rule for the state will be more strict than the federal rule but will still probably not address Cr.

If you look at international limits for Cr they are all over the map. If chromic form it's relatively benign. Cr^{3+} is so insoluble that it never really expresses toxicity. Chromate is very toxic. If any of the Cr^{3+} can be oxidized to chromate then … but the EPA says it's very unlikely. I've seen some papers suggest that some chromate is generated by organisms. But if organic matter in the soil it will tend to be reduced to Cr^{3+}. But even at low levels it is enough to fry a route. In CA they had chromate in deep aquifers at levels of concern for drinking water.

EA What type of soil conditions are a problem ?

MM We're not trying to make a blanket statement about things we haven't looked at so we've focussed on soils in New York. Sandy soil, low organic matter, fairly acid (in Long Island) can result in problems. In Long Island there have been problems with pesticides getting into wells. Wells are fairly shallow.

That's one extreme we're concerned about. In NH they are applying 100's of tons / acre to intentionally manufacture topsoil on old gravel pits. They generate a top soil for turf farming. The gravel pits are right over aquifers. This is pretty obvious that there is nothing to retain metals etc.

Around here subsoil is so compacted the only way water moves along channels and cracks. You get lateral movement across a fragipan or through these cracks. Contaminants that move laterally can enter surface waters.

EA Any recommendations on BMPs ?

MM That's my weak point. In an ideal world you would chose cropping systems that make sense to reduce risk, and apply at agronomic rates. If we are ever forced to apply rates limited by P then the rate will be reduced. Even with lime at 10 t/acre, some are 2/3 lime, 1/3 sludge and the P is not insignificant. You'd be hard pressed to find a dairy farm in NY state that isn't high in P.

If nutrient management plans come in then no point in using biosolids for dairy farm. More for row crops. There is relatively high P:N in biosolids.

EA Around Ottawa, soils are fairly deficient in P except immediately around the dairy farms.

MM Dairy farms here tend to be large, like 500 head.

So Mo is one of my key concerns. The Ontario standard is 4ppm total Mo in soil. Based on background in soil in Ontario being 0.5 – 1 ppm that means we're 's quadrupling the background.

But I guess this needs to be taken in perspective. The US EPA Mo standard will be 40 kg/ha loading which is equal to 20 ppm in topsoil. That's 5 times Ontario's limit. We feel Mo is an Achilles heal for dairy since it is taken up by plants and can therefore enter milk.

EA We will send you a copy of our notes.

Interview Transcript

Call To: Dr. R. Singer, Neurotox Consulting

Date: 20 February 2002 **Time:** 13:00

Taken By: Susan Liver (SL), Erik Apedaile (EA)

Subject: Epidemiological Studies

EA provided an overview of the biosolids program in Ottawa and the approach for this project

EA Could you give us an overview of the field of neuropsychology

RS Neuropsychology is the study of the nervous system underpinnings of behavior and all psychological processes including learning, personality, motivation, planning, thinking, and feeling. My specialty is in neuropsychology and neurotoxicology, which is the effect of toxic substances on the nervous system. I was called in to do an evaluation of a family in Washington State near the Canadian Border. The family had a dairy herd. Their neighbour was paid by the local municipality to accept spreading of sewage sludge on his property. The sludge was spread. Shortly after the cows started to get sick and die and the family started to get sick. Eventually, the family figured out why their herd was ruined and why they were getting sick, and they initiated a lawsuit against the parties responsible for putting the product in. They called me to evaluate the whole family, the parents, grandparent and children for effects of the substances, the sewage sludge, on their nervous system. I did the evaluations that I normally do. I evaluated memory, personality, nerve conduction studies, reviewed the medical records, and spent time looking at everything. I concluded that many members of the family were suffering from brain injuries, which were consistent with neurotoxicity and were consistent with the onset of exposure to sewage sludge. I looked at what evidence we had concerning the sewage sludge. I made my conclusions and published my abstract and presented my paper.

EA What do you mean by consistent with exposure to sewage sludge? What aspects of the sewage sludge – exposure to heavy metals, organics or some sort of synergistic effect?

RS There is a very complex mixture. There were high levels of lead and manganese in the sewage sludge, both of which are neurotoxic. I think that there were a lot of chemicals in that sludge. They took me out to the site of the spreading. I was there for about 15 minutes and I started to get short of breath and started to feel panicky.

EA When you did your site visit, how long had it been since the sludge had been spread on the field and was there a crop growing on the field at the time?

RS I don’t know. I was on the adjacent field, perhaps 15 to 20 yards from the field that had been spread.

EA The spread field in question was adjacent to your client’s field?

RS Yes.

EA Do you know what the distance was from the spread field and your client's home?

RS I guess 50 yards.

EA Do you know if sludge was spread once or if there were multiple applications?

RS There was several applications.

EA Do you recall any visual characteristics of the field? Was the soil bare, was the soil tilled up, was there a crop growing?

RS There was grass growing.

EA Do know the application rate, the method of application and the type of sewage sludge applied?

RS No I don't recall.

EA What do you think were the pathways the contaminants followed from the sewage sludge to your clients?

RS I became sick from the exposure that I experienced. I had an asthma attack and a really bad headache. I felt also that it had a subtle effect on my speech and memory. This was a one time exposure. Later on I was speaking with my clients about what my pathway of exposure had been. They said that there is a gas that is produced, a fluoride type of gas that was odourless but poisonous. My clients suggested that there were odourless gasses that were being formed by the mixture of the sewage and the industrial discharges.

EA Did you notice any odour when you visited the site?

RS We were driving around different places. We would get to places and there would be terrible odours, like rotten flesh, and my client would tell me that there we were near a spot where there sewage sludge dumping. Horrible odours that do not belong around farmlands.

EA Part of what you are describing sounds like lime may have been added to the sludge.

SL Do you recall any ammonia odour?

RS The odour that I recall was similar to what you smell in a morgue, like rotting flesh.

EA Have other people contacted you about this abstract, because what you are describing is fairly significant.

RS Yes, from time to time.

EA Have you heard about this happening in other cases? Have you done other assessments or is this your only one?

RS My only actual first hand experience is with this family.

EA Did they proceed with the lawsuit?

RS Yes. It was very complex. They lost it on an appeal, and from what I was told, they were not allowed to sue a municipality, so they had no case. I don't know why they did not sue the farmer.

EA Were there other families living around the site where the sludge was spread?

RS Yes. I did not get a chance to meet them personally, but my understanding was that they were not doing well either.

EA Were the municipality or state officials aware of your conclusions? Was there any other follow-up on these health complaints?

RS I don't believe so.

SL Are you aware of any other neurotoxicological studies related to biosolids?

RS No, I am not aware of any others.

SL We were surprised that we have not seen more on the subject. I am wondering whether there was something particular about this site or the type of sludge, considering the amount of sludge that is spread. Was it municipal sludge?

RS Yes, it was municipal. I have been working on the data from my study and am willing to share it with you.

EA Thank-you. We appreciate your time this morning.

Interview Transcript

Call To: Dr. Ed Topp, Agriculture Canada

Date: 7 February 2002 **Time:** 13:30

Taken By: Susan Liver (SL), Erik Apedaile (EA)

Subject: Estrogenic Hormones and Pharmaceuticals

EA provided an overview of the biosolids program in Ottawa and the approach for this project

SL The work that you have been doing on estrogenic hormones is what interested us. The literature such as Holling and Sørenson talk about the persistence of estrogen and its accumulation in the environment, particularly in fish. I understand that your work has been more related to the manure context.

ET Both, we have been working on agriculture as a potential source of endocrine disruptors for a few years, and one way that compounds that could be estrogenic could reach the environment via agriculture is by movement off fields that are fertilized with animal wastes or municipal biosolids. The chemicals are somewhat different in the two cases. With the animal wastes, particularly with animals that are pregnant, the females will excrete elevated concentrations of estradiol estrone, perfectly natural compounds, get to the fields and then move to adjacent streams, they might be a problem for obvious reasons. We've simply been characterizing the persistence of those compounds in soil, and we found the natural ones to be very rapidly broken down, which makes sense, because we are not knee- deep in natural female hormones. All mammals are always excreting these chemicals, and they are not around, so intuitively, you would think that they must be fairly labile, fairly rapidly degraded. Based upon our results, that would appear to be the case, with the exception that in the absence of oxygen they are more stable, but whether it is a manure storage system or an anaerobic environment such as aquatic sediments, I would expect them to be more stable under those conditions.

SL That is probable why we are seeing them in biosolids coming from a sewage treatment plant, we are often going through an anaerobic treatment process.

ED Right – that's the animal side. Looking at the biosolids side, there you would be concerned about those chemicals, but also about synthetic chemicals, once example is ethynylestradiol which is a synthetic analog of estradiol, an important component of contraceptive pills. Not the only one, but it is the one that we have looked at.

We did experiments in the laboratory, spiking soils with ethynylestradiol, we found basically the same thing. The compound is very rapidly removed, but under anaerobic conditions it would be more stable. As you said, you would expect it to be more stable in anaerobic environments. This is being looked at quite intensively in a study being led out of the Fresh Water Institute in Winnipeg at the moment.

SL Who is leading that work?

ET Karen Kidd, I can give you her coordinates if you want them.

SL You mentioned that the 17β ethynynlestradiol is only one component of contraceptives that we tend to see in sewage - is Karen working on other elements?

ET No

SL That is one that I have seen mentioned the most often – is that because it is the most significant one?

ET I think it's one of the more significant ones, it's one that is thought to maybe partition into solids. From the agricultural perspective, our first priority would not be very water soluble compounds, because they are less likely to go on the land, they would be more likely to go out in the effluent of a sewage treatment plant, that's why ethynynlestradiol is fairly high up on our list.

The study that I referred to is being done at the experimental lakes area near Winnipeg. What they are doing is contaminating a lake with ethynynlestradiol and they are looking at the impact on everything that you can think of, from bacteria up to fish. How persistent is the compound, all of these kinds of things. It's a whole lake study. It has been going on for maybe a year, so there won't be a lot of data yet.

One other compound that we have looked at is nonylphenol.

SL We have not included the nonylphenols in our list of things to look at because the WEAO Review referred to work that demonstrated that hey are degraded in an aerobic soil environment and therefore not persistent.

ET That's our work.

SL So we don't have them on the list. We were talking with Robert Hale who is doing the BDPE work and he still has some concerns about the nonylphenols, and he has sent us a paper on that, but it is kind of out of our scope.

ET Remember that my focus is fairly narrow. It's: what is the likelihood of chemicals moving from fields to adjacent water. So the questions with nonylphenol are the same ones. If this compound made it into soil, how persistent would it be, and based on our results, we conclude that it would not be very persistent. That does not mean that there would not be other routes of entry of these compounds into the environment.

SL That makes sense. Hale was coming at it from looking at fish, and saw the PBDEs accumulating in fish lipids, and almost by chance found them in biosolids.

ET The brominated flame-retardants have a high probability of bioaccumulating – these are compounds that are very lipohilic that are likely to be much more persistent. We have not looked at them specifically- they may be more of a concern.

We are trying to look at biosolids, if they are used in agriculture a responsible way. That is to say, according to best management practices that should minimise preferential flow movement – movement off site from the point of application. Are the chemicals labile enough that they go away before they are a problem ? What we have seen to date is yes, they are. Then the question is how do we manage application of these materials so they do not move off site before they have they opportunity for these chemicals to break down.

SL Do you have an opinion on best management practices, such as incorporation versus not incorporating of the biosolids into the soil.

ET Yes, all that kind of stuff. That's something that we are looking at with animal wastes, but we are getting geared up to work on biosolids in connection with the program that Tony Ho is organizing. The answer to your question is that there are a bunch of things that you do. You don't put on an excessive rate and you apply the material in such a way that there is good contact with the soil by working the soil before and or after. You don't do it when the slope is excessive; you don't do it when the soil is frozen; all that kind of stuff.

SL We are trying to put together some BMPs for the city.

Have you looked at any other pharmaceuticals related to animal waste?

ET Yes, we are looking at antibiotics, and the question has to do with the issue of compromising therapeutically valuable antibiotics in human medicine. If you put animal waste on land that contains antibiotic residues or antibiotic resistant bacteria, what is the environmental significance of that. Is that going to promote enhanced antibiotic resistance on farms or adjacent to farms that would then represent another reservoir of antibiotic resistant genes that ultimately could be of clinical concern. It's a different route than the food route.

We've been working on this for a couple of years. Probably our strongest experiment consists of looking at cohorts of farms that use antibiotics in pig production, both therapeutically and for growth enhancement of the animals – relatively large amounts of antibiotics, compared to farms that produce pigs organically, where they either never use antibiotics, or only in life and death circumstances. When you compare the two farms, you would expect that if the antibiotics are promoting environmental antibiotic resistance, when you look at microorganisms that you isolate from the soils of those farms, you expect to be able to detect a difference in the abundance or the type of antibiotic resistance from the conventional farms. The bottom line is that what we are seen so far is no evidence of that, which is what I would expect anyway.

EA Why would you expect that?

ET Because there will be relatively little residue that would be excreted by the animals anyway, and in the absence of a selection pressure, in other words in the absence of a continuous exposure top the antibiotics, there is no reason to think that antibiotic resistance would give them a selective advantage, and it should just disappear.

SL Some of the literature speaks about antibiotics in the human context, only 10 to 40% of the antibiotics are taken up by the human body and the rest are passed out of the body as waste.

ET You have to look at it on a case-by-case basis. Some chemicals will be more stable in the gut than others. There is also some literature that is looking at stability of antibiotics in soils.

SL Is that the literature that shows reversion of the antibiotic metabolites back to their original antibiotic?

ET No, I'm thinking about the work that looks at how fast penicillin and tetracycline breaks down. Some of the compounds are more persistent than others.

SL From the literature reviews that I have been looking at, there is a broad range of characteristics of drugs, and that perhaps 30% of them are lipohilic, and so if they make it through sewage treatment, they will end up in the biosolids. There was one reference to metabolites reverting back to parent compounds, which is interesting if you are thinking about any sort of build up of resistance in the soil.

ET OK, to get back to sewage biosolids and therapeutics, we have not looked at that at all, and I don't think that anybody else really has. There is lots of talk about people looking at it, the whole range of pharmaceuticals.

SL There has been some work in Europe where they have started to do measurements of what is in the sewage and what is in the sludge. All of the references are from 2001, so it is all fairly new.

ET Is that Thomas Terne's work? I am working with him on the antibiotic stuff. I guess the answer is that we are still looking at it. You would expect that there might be some compounds that would partition into the solids and could reach land via that route; how much of what is still a question, what is the significance is still a question.

SL There was work done in Britain suggesting that the types of doses that you would be exposed to from a drinking water perspective; if you drank the water for 70 years, you would get the equivalent of one therapeutic dose, so the levels were very low, and at that point, they had dismissed it. There is one paper that looks at entry directly into the food chain from the soil and found uptake of antibiotics from the soil by barley, but it was odd, it was the only one I have seen.

ET I have not seen anything like that, and I can't think of anybody that is specifically looking at that. I think that the best way to think about it is in the context of pesticides. There has been a lot of work and literature and thinking on crop uptake of pesticides. For example, insecticides are very toxic, deliberately applied to fields and crops. The consensus is that you don't get plants taking up organic compounds from the soil and transporting them at any significant rate.

SL The one reference I found was out of Italy. But and large, from what I have seen, if it is lipohilic, it will stay with the soil anyway. If it manages to stay with the biosolids through the treatment plant, it is probably going to stay with the soil rather than being taken up by the plant.

ET The context is what is the likelihood that a plant is going to take up a pharmaceutical from the soil, and I think based upon our experience with pesticides, where most of the work has been done, the likelihood of that happening is very very low.

SL As far as BMPs, you've mentioned a couple of things with respect to the things that you have done, as far as estrogenic hormones go, as long as you are following good management practices it is probably not a concern ?

ET Yes.

SL Is there anything else you would like to add from your perspective on estrogenic hormones or pharmaceuticals?

ET Two thoughts that come to mind are the MOE's initiative to look at pathogen issue in more detail will hopefully be fruitful. Secondly, there are other kinds of organic compounds in sludge, like flame-retardants, that probably should be looked at. My guess is when you put them in the soils they will tie up there and you will never see them again.

EA Have you looked at synergistic effects?

ET No, we have no direct experience there. There was some controversy in the literature the past couple of years over the possible synergistic effect of endocrine disruptors. There was a report published that if you mixed specific endocrine disruptors, there was an additive effect that was much greater than you could account for by summing those up, but that has been refuted by further research. I understand that the thinking now is that the effects are not synergistic.

Interview Transcript

Call To: Susan Springthorpe, Department of Biochemistry, Microbiology and Immunology
Faculty of Medicine, University of Ottawa

Date: 12 March 2002 **Time:** 16:00

Taken By: Erik Apedaile (EA)

Subject: Health Aspects of Biosolids Land Application

Reviewed and revised by Springthorpe, March 20, 2002

EA provided an overview of the biosolids program in Ottawa and the approach for this project and the objective of the interview.

EA What would you say is are the key health issues related to land applying biosolids?

SS You have to address both air and water. With respect to the public, the major trigger is odour, even if it is not the most important. With respect to air, the key issue is endotoxins. People's response to endotoxins is variable – each person will react differently. Endotoxins are the most likely explanation for the rapid onset symptoms that we see reported in the media or in anecdotal reports. It is rare to see whole groups of people becoming sick; we can't dismiss these anecdotal reports.

EA Would endotoxins move in air in the same way as bacteria and viruses that are in aerosols or on dust particles?

SS Yes, endotoxins are particulate – part of the cell wall.

My involvement with biosolids at the moment is a research proposal for MOE OMAFRA and Ag Canada. I am trying to integrate into it some field level monitoring for endotoxins. There is absolutely no data in the literature on field measurement of endotoxins.

EA How do you propose to measure endotoxins in the field?

SS The method is fluorescence polarization – the samples are collected using impingers. It allows you the quickly calibrate and measure endotoxins in the field. It would be a bit expensive to set up, but after the initial investment you can get a lot of samples cheaply. You could also measure pathogens in the sample you collect, but then you are looking at expense and time for analysis.

EA While there is nothing in the literature on endotoxins related to land application, there is some data from sewage treatment plant settings.

SS The issue of worker exposure to endotoxins has been well studied. The methods for those studies have been well established and there has been more effort because of the industrial setting. But, there is nothing in the literature on endotoxins and land application of biosolids.

Endotoxins are there in very high quantities in biosolids, but there is no agreed level that causes symptoms.

EA Are there defined symptoms related to exposure to endotoxins?

SS No. But whereas infection from pathogen exposure usually takes a little time to develop, effects of exposure to endotoxins can be very rapid, and are not associated with a single set of symptoms/disease. There has been effort on endotoxins in industrial settings. There is nothing in the literature with respect to land application of biosolids.

EA You mentioned that water issues also need to be addressed.

SS Yes the water issues are important, but the most risk to water probably comes from large scale liquid applications and from stockpiles of biosolids which are not spread for some time. The MOE wants to look at a whole variety of variables, including the influence of tillage, application rates and soil moisture. I am interested in looking at biosolids versus manure to see if there are some parallels between manure and biosolids that are of similar solids content. The problem with researching biosolids in the field is that you can only apply a site once every 5 years. If parallels could be drawn between manure and biosolids, we could look at manure and extrapolate to biosolids.

There was an interesting study out of the University of Hawaii that looked at the effect of polyacrylamide on pathogen movement. I am trying to get some more details about it.

There are lots of questions about polymer. They are potentially a concern. In some cases, they are being applied directly to soil to improve the soil structure by increasing the soil water holding capacity.

EA What do you think about ongoing monitoring of environmental effects from land application?

SS I am not a big proponent of ongoing monitoring. I think that it has to be based upon a good rationale. A bigger issue is understanding the surficial geology of potential land application sites. Some of the areas where biosolids have been spread in the past raise some real red flags because there may not have been lots of topsoil. It is better to put resources into verifying soil depth and types than into monitoring. Monitoring can be a bit like looking for the needle in a proverbial haystack – it is difficult to extrapolate from negative results to see that the needle is not there.

EA One of our proposed Best Management Practices is to verify soil depth as a part of the site assessment. What do you think about the potential for pathogen re-growth?

SS The issue of pathogen re-growth has been largely ignored. Many bacteria will survive in the environment. For example, viable but not culturable bacteria will not be detected, but they are not dead. They can recover and re-grow. When bacteria run out of food they can become quiescent and difficult to detect in routine culture. Activity of other bacteria and fungi in the soil in breaking down organic materials can subsequently liberate substances that they can use for regrowth.

Another issue which is of concern is the preferential pathways which may exist in some soil types and on uncultivated land which promote rapid movement of the applied materials to depth, particularly after rain. Once in a more 'anaerobic' portion of the soil or even in saturated soils or groundwater, many enteric pathogens may survive much better than in the top few cm of soil. Best management practices designed to retain the microorganisms close to the surface of the soil will likely present the least risk of groundwater contamination.

Appendix B

WEAO Report – Executive Summary

EXECUTIVE SUMMARY

Land application of sewage biosolids has been widely practiced in North America (including Ontario) and Europe for many decades. Over the years, regulations and procedures have been developed to manage the application, and protect human and animal health and the environment. A considerable amount of scientific study has been undertaken to support the development of the regulations, and to confirm the effectiveness of the application procedures. However, the public still has concerns that land application may be unsafe because it involves human and industrial waste.

Although diverse, public concern about the detrimental health and environmental effects of sewage biosolids land application has tended to coalesce around the following main issues:

1. Surface and groundwater pollution,
2. Fate and effects of pathogens,
3. Fate and effects of heavy metals and
4. Fate and effects of organic contaminants.

In the last few years, there has been an increase in the number of large Ontario jurisdictions moving towards biosolids beneficial use. This has raised public awareness and interest in the impact of biosolids land application, making it even more critical to ensure that the safety of biosolids beneficial use is scientifically confirmed.

Project Undertaking and Objectives

This study is part of an ongoing effort by the Ontario government and municipalities to update and improve land application regulations and procedures.

The Water Environment Association of Ontario (WEAO) undertook this project in conjunction with the partners representing various municipalities, Environment Canada, Ontario Ministry of the Environment (MOE) and Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA).

The objectives of the project were:

1. Review, assess, and summarize information assembled from literature and consultation with credible non-government organizations, farming associations, experts and regulatory agencies (Stakeholders) regarding the fate and significance of contaminants in sewage biosolids after they are applied to agricultural lands.

2. Use the information to divide specific contaminants in sewage biosolids into two groups:

   Group I – Contaminants which have sufficient credible scientific information to assure the public that the current agricultural land application program/guidelines are adequate to protect the well beings of soils, crops, animals, human health, ground and surface water qualities.

EXECUTIVE SUMMARY – cont'd

Group II – Contaminants which do not have sufficient credible scientific information to assure the public that the current agricultural land application program/guidelines are adequate to protect the well beings of soils, crops, animals, human health, ground and surface water qualities.

3. Recommend a long-term study program that would allow sewage biosolids generators, the federal and provincial government agencies to complete the information gaps and identify actions that would be necessary to mitigate any adverse effects that may be caused by the presence of specific contaminants in sewage biosolids. The studies should be prioritized based on needs and consensus reached between Stakeholders.
4. Provide comprehensive Terms of Reference for the top 3 studies identified in the long-term study program.
5. Disseminate the study findings and recommendations to the Stakeholders and municipalities through report(s) and workshop(s). The information package should also include a well-organized bibliography (by topic/issue and where the reference materials can be obtained/ordered) and one copy of an appendix containing all the reference materials reviewed by this study.

Information was solicited from a broad range of sewage biosolids stakeholder and expert groups, concerning current and emerging issues and research/regulatory programs relating to the agricultural land application of sewage biosolids. Information gathering focused on the fate of metals, organic contaminants, pathogens, and other contaminants in land-applied biosolids and on their significance for soil, crops, surface and groundwater quality, and human and animal health.

For survey purposes, the stakeholders were subdivided into two groups:

Group 1 - Stakeholders located in Ontario
Group 2 – Regulators and Experts located outside Ontario

Separate questionnaires were prepared and submitted to the groups.

Contaminants Of Concern

From the stakeholders, Technical Steering Committee, and consultants' input, the following list of contaminants was developed:

- Heavy Metals including Regulated and Unregulated
- Pathogens
- Trace Organics, including Volatile Organic Contaminants (VOCs), Polychlorinated Biphenyls (PCBs), Polynuclear Aromatic Hydrocarbons (PAHs), Pesticides, etc.
- Linear Alkylbenzene Sulphonate (LAS) Surfactants
- Endocrine Disrupter Compounds (EDCs) including Alkylphenol Surfactants (APs), Estrogenic Hormones
- Dioxins and Furans (PCDD/Fs)
- Pharmaceuticals

EXECUTIVE SUMMARY – cont'd

- Radionuclides
- Nutrients including Nitrogen and Phosphorus

Literature Review

Literature reviews were conducted for all of the above specified contaminants of concern. The abstracts of recent publications (1995 to the present) were entered into an ACCESS database for ease of access.

The literature review included the following:

1. Heavy Metals In Sewage Biosolids Applied To Agricultural Land

   The review of literature data on the fate and effects of heavy metals in sewage biosolids applied to agricultural land led to the following findings and conclusions:

   - Sewage biosolids are products of wastewater treatment and depending upon sewer use controls, they can contain variable amounts of whatever heavy metals are used, domestically and industrially, in the sewerage district. However, biosolids quality has improved dramatically over the years due to industrial pretreatment programs, household hazardous waste education and changes in water supply management.

   - Large amounts of research have focused on a few heavy metals considered to be the most hazardous and guidelines/regulations for land application of sewage biosolids have been developed to limit loadings of these constituents to agricultural land. Agronomic rates are more restrictive than the metals loading rate.

   - There is much less Canadian than US and international research on the effects of heavy metals in land applied sewage biosolids. However, Canadian and in particular, Ontario recommended practices are among the most conservative in the world. Considering the absence of detrimental effects in studies with high metal concentrations and application rates, it is concluded that the recommended land application practices in Ontario present no significant risk to humans and the environment.

   - The regulated metals can be considered Group I contaminants for which current Ontario guidelines are adequate to protect the well being of soils, crops, animals, humans and ground and surface water qualities.

   - The following unregulated metals and compounds in biosolids were considered: aluminum, antimony, asbestos, barium, beryllium, boron, cyanide, fluoride, manganese, silver, thallium and tin. Based on very limited information, it was concluded that loadings of unregulated metals in land applied sewage biosolids are unlikely to exceed Ontario MOEE "Effects Based Limits" developed for contaminated site cleanup of soil for agricultural

EXECUTIVE SUMMARY – cont'd

use, however, a few of them, e.g., silver, antimony, may exceed the Ontario MOEE "Background Limits". Thus, the unregulated heavy metals are Group II contaminants requiring further research.

2. Pathogens In Sewage Biosolids Applied To Agricultural Land

Human health impacts of pathogens in land applied sewage biosolids have been comprehensively and frequently reviewed.

The Washington University concluded in its 1997 literature review study (Gaus et. al. 1997) that:

- in most cases, pathogens are retained in the upper 5 to 15 cm of soil and parasites are generally strained out at the soil surface because they are larger and heavier than bacteria and viruses;
- very few bacteria have been detected in ground water from biosolids-amended sites;
- even through surface water runoff has been found to contain some indicator bacteria, bacterial contamination of surface water seems unlikely, as the survival time of enteric bacteria and viruses in soil is relatively short.

The US EPA Health Effects Research Laboratory concluded in its 1985 literature review study (Kowal, 1985) that spray application of biosolids did not represent a health threat for individuals more than 100 m downwind of the application site. Organisms transported in aerosols are much more susceptible to inactivation than in soil due to solar radiation, desiccation and high temperature.

The Ohio University conducted a three-year epidemiological study between 1978 and 1982 (US EPA, 1985). The study evaluated the health risks of land application of people living in farms that received biosolids application and another group of 130 people living in farms that did not receive biosolids application. The study team comprised of infectious disease specialists, toxicologists and epidemiologists. The study concluded that there were no significant health risks to people and their domestic animals when biosolids were applied at the rate of 4 to 10 dry tonnes/ha/year. Ontario guidelines limit biosolids application to 8 dry tonnes/ha/5 years.

Pike and Carrington reported in 1986 (Pike and Carrington, 1986) that surveillance of human and animal disease in the United Kingdom showed that properly managed land application of stabilized sewage biosolids prevents infection from sewage biosolids–born pathogens following land application.

EXECUTIVE SUMMARY – cont'd

In spite of similar conclusions reached by different experts in human health studies, some public still are skeptical or not convinced of the evidence that sewage biosolids can be safely utilized on agricultural land. They fear that biosolids application may be a major cause of surface water and private well contamination and aerial disease transmission. These concerns were expressed by some stakeholders at the WEAO Biosolids Stakeholder Workshop held in December 1999 and in recent newspaper articles and television programs. The concerns arise from a variety of issues including: the recent E.coli contamination of the Walkerton Ontario water supply; evidence that microbial contamination of the tile drainage water may occur rapidly following animal manure application; and perceived inadequate monitoring and control of sewage biosolids application.

Public acceptance is crucial to the success of land application of sewage biosolids programs. It is recommended that a task force involved medical experts, farmers, public representatives and biosolids generators and regulators be formed to explore pathogen issues and build consensus to resolve the issues.

3. Organic compounds in sewage biosolids applied to agricultural land

The World Health Organization (WHO) Working Group on the Risk to Health of Chemicals in Sewage Sludge Applied to Land has concluded that 'the total human intake of identified organic pollutants from sludge application to land is minor and is unlikely to cause adverse health effects".

However, during the Stakeholder Workshop a particular concern was raised re: some organic compounds namely, dioxins and furans, endocrine disruptors (mainly alkyphenol ethoxylates), and surfactants (mainly linear alkylbenzene sulphonates). Based on the concerns raised at the Stakeholder Workshop, Sections 10, 11 and 12 of this report provided a literature review of these organic compounds, and summary of the findings is provided below.

4. Surfactants In Sewage Biosolids Applied To Agricultural Land

Surfactants and their degradation products are not regulated by either the Ontario "Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land" or the US EPA Regulation 503 "Standards for the Use or Disposal of Sewage Sludge". Some European jurisdictions have introduced limits for linear alkylbenzene sulphonates in land-applied biosolids but no justification for these numbers was identified.

The literature review revealed that high concentrations (e.g., thousands of mg/kg dry wt.) of linear alkylbenzene sulphonates or their degradation products can occur particularly in anaerobically stabilized biosolids. However, these compounds degrade rapidly (within a few days or weeks) under aerobic soil conditions and do not present a significant health or environmental hazard.

EXECUTIVE SUMMARY – cont'd

Based on the above finding, it was concluded that linear alkylbenzene sulphonate surfactants fall into the Group I category, not requiring further study. However, the authors are not aware of linear alkylbenzene sulphonate data for Ontario soils and suggest that some be obtained.

5. Endocrine Disruptors In Sewage Biosolids Applied To Agricultural Land

   Alkylphenols and their degradation products are not regulated by either the Ontario "Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land" (MOEE and OMAFRA 1968) or the US EPA Regulation 503 "Standards for the Use or Disposal of Sewage Sludge". However, Switzerland banned the use of nonylphenol ethoxylates in fabric detergents in 1986 and some other European jurisdictions have introduced limits for nonylphenol concentrations in land applied biosolids. No basis was provided for the setting of these particular limits.

   The literature review indicated that:

   - Alkylphenols and alkylphenol ethoxylates do not persist in soils for extended periods and, in fact, are readily broken down by the microbial populations in the soil.
   - The initial concentrations of alkylphenols and alkylphenol ethoxylates occurring immediately after sewage biosolids application should not impact crop growth, or present any leaching potential because the uptake of alkylphenols by plants is minimal. Additionally, no leaching occurs into the groundwater and there is no transfer via the food chain to animals.
   - Endocrine Disruptors such as alkylphenols and alkylphenol ethoxylates are therefore considered as Group I contaminants, for which no further study is recommended, at this time.
   - Estrogenic hormones that are considered endocrine disrupting compounds cannot presently be analyzed in sewage biosolids. Therefore, these compounds are considered Group II contaminants for which further study is needed.

6. Dioxins And Furans In Sewage Biosolids Applied To Agricultural Land

   There are few Canadian guidelines or regulations for dioxins in soils. The CCME (Canadian Council of Ministers of the Environment) interim assessment criterion and interim remediation criterion for total TEQ concentration in soil are both 10 ng/kg dry weight. The "Guideline for Use at Contaminated Sites in Ontario" reports a background TEQ concentration in soil of 7 ng/kg dry weight and an effects based guideline of 10 ng/kg dry weight for clean-up of land for agricultural use.

EXECUTIVE SUMMARY – cont'd

There are currently no guidelines in Ontario to regulate the concentrations of dioxins and furans in sewage biosolids for application on agricultural land. The literature review of available information indicated that dioxins and furans concentrations in sewage biosolids are extremely low. At the maximum application rate of 8 dry tonnes/ha/5 years, and assuming there is no biodegradation of dioxins and furans in soil, biosolids containing median concentrations of dioxins and furans can be applied repeatedly to the same field 66 times or 330 years before the "Background Based" soil concentration limit would be reached (Ref. Table 9.6). Thus, they are Group I contaminants for which no further study is necessary, at this time.

7. Pharmaceuticals In Sewage Biosolids Applied To Agricultural Land

   There is very little information on pharmaceutical concentrations in sewage biosolids or on the environmental behaviour and ecotoxicology of these biologically active substances.

   Due to the lack of data, pharmaceuticals are considered Group II compounds which need further information.

8. Radionuclides In Sewage Biosolids Applied To Agricultural Land

   Whereas heavy metals and other potentially toxic elements such as arsenic and selenium in sewage biosolids have received considerable attention over the years, radionuclides are seldom mentioned and there is no provision for them in present land application guidelines/regulations. A search of international literature from 1995 to the present identified a small number of reports (none Canadian) on radionuclides in sewage biosolids.

   Since long-lived radionuclides are excluded from Ontario sewer systems and medically used radionuclides are short-lived, it is concluded that radionuclides are Group I contaminants for which no further study is necessary, at this time.

9. Nitrogen And Phosphorus In Sewage Biosolids Applied To Land

   Literature findings revealed that currently in Ontario, estimates of potential plant available N (PAN) following biosolids application to land are based on extensive experience of animal manure use, limited experience of biosolids use, knowledge of biosolids and soil properties, and an incomplete understanding of the effects of various biosolids management techniques and environmental conditions. Although imperfect, these estimates are probably adequate for biosolids use according to the present guidelines which call for a maximum addition of 135 kg/ha of plant available N to land in biosolids during a 5-year period. This practice severely limits N buildup in the soil and avoids potential environmental

EXECUTIVE SUMMARY – cont'd

problems associated with more frequent applications and larger N loadings. Similarly, present Ontario practice limits biosolids P buildup in soil, facilitating efficient use of the P fertilizer value and avoiding potential environmental problems associated with more frequent applications and larger P loadings.

Based on the literature review it was concluded that available biosolids N and P information is adequate in relation to present land application practice. However, it is recommended that adoption of a more sophisticated site-specific approach to biosolids N management such as that currently being developed for the U.S.A. should be considered prior to recommending increased biosolids applications to land in Ontario.

Group I And Group II Contaminants

Based on the findings of the literature review which were discussed at the Technical Steering Committee meeting and endorsed by the Technical Steering Committee members, Table ES-1 allocates the contaminants of concern to Group I (no additional studies recommended), or Group II (additional studies required).

EXECUTIVE SUMMARY – cont'd

TABLE ES-1
Group I and Group II Contaminants

CONTAMINANT OF CONCERN	GROUP I	GROUP II	GROUP II COMMENTS
Heavy Metals – Regulated and Unregulated	Regulated	Unregulated	Data required for unregulated heavy metals in Ontario biosolids
Pathogens		X	Data required to address potential risks of pathogens in biosolids for water quality and human health.
Trace Organics - Volatile Organic Contaminants (VOCs), Polychlorinated Biphenyls (PCB's), Polynuclear Aromatic Hydrocarbons (PAHs), Pesticides	X		
Linear Alkylbenzene Sulphonate (LAS) Surfactants	X		
Endocrine Disruptors (EDCs) - Alkylphenol Surfactants (APs), Estrogenic Hormones	Alkylphenols	Estrogenic Hormones	Analytical methods development required for estrogenic hormones
Dioxins and Furans (PCDD/Fs)	X		
Pharmaceuticals		X	Analytical methods development required. Data required for pharmaceuticals in Ontario biosolids
Radionuclides	X		
Nutrients - Nitrogen and Phosphorous	X		

As seen in Table ES-1, four groups of contaminants have been allocated into the Group II category. Of these contaminants, hormones that are considered endocrine disrupting compounds and pharmaceuticals cannot presently be analyzed in sewage biosolids.

<u>Recommended Additional Study For Group II Contaminants Of Concern</u>

Based on the findings and conclusions from the various report sections, Table ES-2 provides a summary of the recommended studies for the Group II contaminants of concern. The allocation of contaminants to Group II and recommended studies were discussed at the Technical Steering Committee meeting and endorsed by the committee members.

EXECUTIVE SUMMARY – cont'd

TABLE ES-2
Summary of Recommended Studies

GROUP II CONTAMINANT OF CONCERN	RECOMMENDED STUDIES	COMMENTS
Unregulated Heavy Metals	Conduct a survey of unregulated heavy metal concentrations in Ontario sewage Biosolids and agricultural soils	
Pathogens		Form a task force with representatives from the wastewater treatment and medical communities, and the public to explore and build consensus on such issues as the principles that should be used to define risks and acceptable risks, develop and monitor studies that would confirm/recommend improvements to current application program.
Hormones and Pharmaceuticals	Develop analytical methods for measuring pharmaceutical and estrogenic hormones in sewage biosolids. Conduct a survey of pharmaceuticals in Ontario sewage biosolids.	Research in progress at the Agriculture and Agri-Food Canada Research Centre, London, ON to determine concentrations and fate of estrogenic hormones in land applied animal manure should be supported

<u>Terms Of Reference For The Identified Group II Contaminants</u>

In order of priority, pathogens, unregulated metals and pharmaceuticals and hormones in land applied sewage biosolids were identified for the Three High Priority Studies. The research recommendations are as follows:

1. Pathogens

   Form a task force involving medical experts, farmers, public representatives and biosolids generators and regulators to explore pathogen issues and build consensus to resolve the issues. Some of the tasks can include, but are not limited to:

   - monitoring information/tools being generated by recent Water Environment Research Foundation (WERF) and National Academy of Science (NAS) studies aiming at assessing the health impacts that may be attributable to sewage biosolids land application program;

EXECUTIVE SUMMARY – cont'd

- using the US study information and experience as reference to determine how Ontario should define risks and acceptable risks associated with sewage biosolids land application;

- developing and monitoring studies that are necessary to measure and assess risks;

- developing and monitoring studies to confirm and/or improve current biosolids; management and application practices and/or guidelines for public health and environment protection;

- developing and monitoring studies to increase public confidence and acceptance of the biosolids application program;

- disseminating information to stakeholders including the media and general public.

2. Unregulated Metals

   - A survey should be conducted to obtain a representative database of information for unregulated metals in Ontario sewage biosolids and agricultural soil.

3. Pharmaceuticals and Estrogenic Hormones

   - Develop analytical methods for measuring pharmaceutical compounds and estrogenic hormones in sewage biosolids.

   - A survey should be conducted to obtain a representative database of information for pharmaceutical compounds and estrogenic hormones in Ontario sewage biosolids.

   Also, research in progress at the Agriculture and Agri-Food Canada Research Centre, London, ON to determine concentrations and fate of estrogenic hormones in land applied animal manure should be supported. (Terms of reference for this activity are not presented in this document).

Appendix C

Unregulated Metals – Supplemental Information

TABLE C-1
Comparison of Ottawa Unregulated Metals

Unregulated Metal	Average Ottawa Concentrations	Typical Range (Lester)	Typical Median (Lester)
Al	12,800	8,100 – 51,200	14,000
Sb	8	3 - 44	10
Ba	492	272 – 1,066	539
Be	16.3	1 – 30	3
B	9	15 – 1,000	50
Ag	27	5 – 150	20
Tl	14	0.1 – 89	26
Sn	38	40 – 700	120

TABLE C-2
Sources of Heavy Metals

Metal	Sources
Al	Sources include alloys, castings, construction materials, dye and paper manufacturing, aluminum sulphate (alum) used for water treatment (Trail Road, 2000).
Sb	Sources include flame retardant materials, paint pigments, ceramic enamels, glass and potters, plastics, semiconductors, infrared detectors and diodes (Trail Road, 2000).
Asbestos	Sources are fireproofing materials, building materials, brake linings, clutch facings, electrical insulation and certain paper products (CCME, 1987). Asbestos fibres can also be introduced directly into water supplies from asbestos cement pipes.
Ba	Sources are manufacture of metal alloys, paints, pigments, paper, soap, rubber, linoleum and cement processing of diesel fuels, medical and cosmetics.
Beryllium	Sources are the production of light alloys, copper and brass, X-ray tubes and neon signs, catalyst in manufacture of organic chemicals, and ceramics (Trail Road, 2000).
Cyanide	Sources include industries involved in the production of acrylonite, adiponitrile and methylmethacrylate (CCME, 1987). Sodium cyanide is used in the extraction of gold and silver from low-grade ores, in steel production, in electroplating and as an intermediate for chemical syntheses. Some compounds containing cyanide may also be used as pesticides.
Fluorides	Fluorides are used in metallurgical processes, phosphate fertilizers, insecticides and herbicides and the refining of uranium ores. It is often added to domestic water supplies to reduce dental cavities.
Iron	Sources include the corrosion of iron and steel, paints and electrical materials (Trail Road, 2000).

TABLE C-2
Sources of Heavy Metals

Metal	Sources
Manganese	Sources are metal alloys, dry cell batteries, paints and varnishes, glass, ceramics and fertilizer (Trail Road, 2000).
Silver	Sources are photographic materials, sterling and plated ware, electrical and electronic products (e.g. batteries), brazing alloys and solders and fungicides (Trail Road, 2000). Photographic industries use almost 44% of the total silver used (Lester, 1987).
Strontium	Sr is a metallic element of the calcium group. Its sources are medicine, ceramics and pyrotechnics (Trail Road, 2000).
Thallium	Sources are alloys, electrical apparatus, optical equipment, photographic and ceramic formulations (Trail Road, 2000).
Tin (Sn)	Sources of tin are corrosion control, electrical condensers, bottle cap liners and food packaging and fuses (Trail Road, 2000).
Titanium	Sources of titanium include industries such as mining and smelting, the manufacture of pigments, the metal and its compounds (CCME, 1987).
Vanadium	Sources of vanadium are alloy steels and it is also present in crude oil and coal (Trail Road, 2000). Approximately 83% of vanadium consumed is used in the manufacture of iron and steel alloys (Lester, 1987)

TABLE C-3
Removal in Wastewater Treatment Process

Metal	Removal (%)	Concentration Factor	Comment
AL	94%.		ROPEC data
Sb	30 to 90%.		Typical removal in activated sludge process
Asbestos	No data		
Barium	84%.		ROPEC data
Beryllium	50 to >75%.		Typical removal in activated sludge process
Boron	0%.		ROPEC data
Cyanide			No data
Iron	74%.		Typical removal in activated sludge process
Manganese	11%.		Typical removal in activated sludge process
Silver	>38%.		Typical removal in activated sludge process
Strontium	19%.		Typical removal in activated sludge process
Thallium	70%.		Typical removal in activated sludge process
Tin (Sn)	0 to 90.7%.		Typical removal in activated sludge process
Titanium	No data		
Vanadium	25%.		Typical removal in activated sludge process

TABLE C-4
Fate in the Environment

Metal	Comment
AL	Capable of forming numerous complex ions with fluoride, sulphate and organic matter (CCME, 1987). Numerous organic materials, such as humic acid, fulvic acid, reducing sugars and organic acids are capable of mobilizing aluminum in the aquatic environment.
Sb	Sb has an affinity for clay and mineral surfaces (CCME, 1987). Coprecipitation with hydrous iron, manganese and aluminum may also occur. Field surveys have indicated that antimony is bound to sediments but the degree and extent of binding are unknown. Bioconcentration factors of 40 and 16,000 were reported for freshwater fish and invertebrates, respectively.
Asbestos	Sediment does not have an adsorptive affinity for solid materials, such as asbestos (CCME, 1987). However, numerous inorganic and organic materials may be adsorbed to asbestos. More than 60 compounds have been observed to be adsorbed to asbestos, mostly as n-alkanes, with little, if any polycyclic aromatic hydrocarbons. Fish living in water with high asbestos fibre concentrations do not accumulate levels of asbestos which could be a threat to human health (CCME, 1987).
Barium	Very little barium would occur in solution, as a result, barium concentrations of sediments (90-2300 mg/kg) are higher than those reported in fresh water (<3-150ug/L) (CCME, 1987). Barium accumulates in some marine biota.
Beryllium	Beryllium has a complicated coordination chemistry and can form complexes, oxycarboxylates and chelates with a variety of materials (CCME, 1987). During the process of weathering, Be concentrates as a hydrolysate in the clay mineral fraction and does not enter solution to any appreciable extent.
Boron	No data
Cyanide	The cyanide ion is not strongly adsorbed and retained in solids (CCME, 1987). Numerous microorganisms have been identified which are capable of degrading free cyanide and cyanides may be removed from waste streams by biological treatment.
Fluoride	one of the main ions responsible for solubilizing beryllium, aluminum, scandium, niobium, tantalum, iron and tin in natural waters. F concentrations in inland lakes are believed to be regulated
Iron	Microorganisms and fungi is soil and subsurface environments may mobilize iron and bring it into solution (CCME, 1987). In anaeraobic sediments, ferric oxide and hydroxides may be reduced when certain strains of microorganisms and an organic food source are present. Aerobic bacteria may catalyze the oxidation of ferrous iron, resulting in the precipitation of ferric hydroxide.
Manganese	Manganese is similar to iron in its chemical behaviour and is frequently found in association with iron (CCME, 1987). Mn is an essential trace element for microorganisms, plants and animals, and hence, is contained in all or nearly all organisms.
Silver	Silver is insoluble at pH >7.5 (CCME, 1987). Ag is mobile at low pH and may complex with sulphur, arsenic, antimony, tellurium and selenium. As pH increases, silver tends to precipitate. Bioconcentration in organisms and fish is relatively low (i.e. less than 100x) and does not appear to be subject to biomagnification.
Strontium	Exposure to strontium-90 particles will show a rapid accumulation of the isotope in bone tissue (http://nobel.scas.bcit.ca/resource/ptable/sr.htm, Jan 2002). Because it is so highly radio-active, it interferes with the production of new blood cells and eventually causes death. The action of strontium is closely related to that of calcium, although retention of Sr varies inversely with calcium intake (http://www.acu-cell.com/bbs.html, Jan 2002). Supplementing large amounts of strontium increases calcium retention (but not magnesium), while at the

TABLE C-4
Fate in the Environment

Metal	Comment
	same time Sr lowers stomach acid levels, WBC, insulin, fluoride, bismuth, germanium and silicon. In order to help with osteoporosis, or for any of the above effects to take place, over 1,000 mg of strontium has to be ingested daily (versus a few mg/day obtained through regular food intake), and at those amounts, various medical problems may be experienced. As a result, strontium does not appear to serve any unique or specific purpose that no other, or better tolerated nutrient could fulfill
Thallium	Concentrations of Tl have been reported in various media: soil, 0.2 mg/kg; vascular plants, 0.03-0.3 mg/kg; the soft tissue of fish, 0.08 mg/kg; and the human body which has a total body burden of 0.1-0.5 mg thallium with muscle containing the highest concentrations (CCME, 1987). Tl is strongly sorbed by montmorillonite clay; at pH 8.1, over 95% of the thallium (100 ug/L) was removed from the water column by the clay, hectorite (1 g/L) within 24 hours (CCME, 1987). At pH 4, however, sorption was not effective in thallium removal. Tl is also detected only in the sedimentary phase of soils. Bioaccumulation and biomethylation may occur with thallium.
Tin (Sn)	Some divalent tin may occur in anaerobic sediments but there are few studies on the bioaccumulation of tin.
Titanium	Titanium is not considered to be an essential element for either plants or animals. Ti is accumulated in hard siliceous tissues, and is present in terrestrial plants such as edible vegetables (<0.02-3 mg/kg), mammalian muscle (<1-2 mg/kg) and fish (0.2 mg/kg).
Vanadium	Vanadium is highly mobile in neutral or alkaline environments (CCME, 1987). Its mobility decreases in oxidizing and acidic environments, whereas in reducing environments it is nearly immobile. There are few studies on the bioaccumulation of vanadium but its uptake has occurred in higher plants showing elevated V concentrations. There is little evidence for biomagnification.

Appendix D

Health Aspects of Biosolids Land Application Access Database

March 2002 Health Aspects of Biosolids Land Application Access Database

The Health Aspects of Biosolids Land Application Database is a compilation of relevant, published research related to human health and the land application of anaerobically digested, dewatered biosolids. You can find all the data you need in a single search right from your desktop. Whether you are looking for the most recent research on pathogens or the articles written by a particular author, this tool will help you quickly find the information you need. Once you have found the information, you can immediately save the information as a query or print a formatted report. There are three tables of information: articles (containing journal articles), category (containing summary of category from the report), and interview (transcripts of interviews conducted).

System Requirements:

The Health Aspects of Biosolids Land Application Database requires a system with Windows 9x, NT or 2000. Microsoft Access must be installed on your computer in order to use the database. This database was created in Microsoft Access 97, if you have version 2000, the program will ask you to convert the file. If you convert the file to read only and add information to the database, Access 97 will not be able to use the 2000 file.

Installation Instructions:

The Health Aspects of Biosolids Land Application Database can be run from the CD-Rom drive but will be faster if the file is copied on to the hard drive of your computer or your organization's server.

1. Insert CD into your CD-Rom drive.
2. Save as Health Aspects of Biosolids Land Application Database in the appropriate folder on your computer.
3. Double-Click on saved file to open database.

Search Database:

To search the database for specific records or groups of records a query must be run.

1. Open Database
2. Click on query tab
3. Select Article icon
4. Click on design
5. Pick the field you would like to search and enter the search words in the Criteria row, using a star to begin and finish the word. For example to search all articles Sorber is a principal or participating author for you would input *Sorber* into the author field in the Criteria row
6. Click on the exclamation point in the tool bar to run the query

To Create a Report:

To create a report that displays the information in a columnar format.

1. Open Database
2. Click on report tab
3. Choose new
4. Click on Report Wizard
5. Choose a query table to work with, use drop down box. For example choose “Article”
6. Click on each field you would like in your report and click on the arrow to insert it into the table design
7. The report may be sorted alphabetically by a field. If you wish to choose this option, select a field from the drop down box
8. Choose the layout and orientation for your report, most common are columnar and portrait
9. Next select the style for your report
10. Select a title for the report
11. Click finish and your table will be displayed
12. To format your report, return to the report tab and click Design
13. Select any of the boxes and right click, scroll down to Properties, select your options
14. Click and drag any box to the preferred size

If you would like additional instruction, in the Help drop down menu select contents and index and type the word(s) you want to find.

Appendix E

Dr. Donald Charles Cole Curriculum Vitae

Curriculum Vitae

April 2, 2002

Donald Charles Cole

Personal Information

Institute for Work & Health:

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E-mail: donald.cole@utoronto.ca
Website: www.utoronto.ca/phs

D.O.B:	1952 October 12
Citizenship:	Canadian
Languages:	English, Spanish & French

Education

1970-72	BSc Program, Faculty of Arts and Sciences, University of Toronto
1973-78	MD, Faculty of Medicine, University of Toronto
1979	Postgraduate course in the Epidemiology of Tropical and Parasitic Diseases, Division of Community Health, University of Toronto
1987	Tutorial Skills for Small Group Learning Workshop, McMaster Faculty of Health Sciences
1989	DOHS or Diploma in Occupational Health and Safety, Occupational Health Program, McMaster University
1991	**MSc** in Design, Measurement and Evaluation of Health Services, Dept of Clinical Epidemiology and Biostatistics, McMaster University

1995	Summer graduate course in Reproductive Epidemiology, University of Michigan School of Public Health, Department of Epidemiology

Current University Status

University Of Toronto

Associate Professor	Community Medicine/Epidemiology, Department of Public Health Sciences, Division of Community Health, Faculty of Medicine, University of Toronto : 2001-

Mcmaster University

Associate Professor (part-time)	School of Geography and Geology: 1998-
Associate	Occupational Health and Environmental Medicine Program: 1993-
	Institute for Environment and Health: 1992-

Other

Academic Associate

Centre for Research in Earth and Space Technology: 2000 -

York University

Associate Member

Graduate Faculty, Division of Community Health: Nov 1998-2003

Institute for Environmental Studies: 2000-2003

University of Toronto

Associate Graduate Faculty

Department of Family Studies, University of Guelph: 1995-

Department of Kinesiology, University of Waterloo: 1997-

Associate

Hamilton-Wentworth Social & Public Health Services, Public Health Research Education & Development (PHRED): 1994-

Father Sean O'Sullivan Research Centre, St. Joseph's Hospital: 1995-

Adjunct Professor, School of Science & Technology, University College of Cape Breton: 1999

Professional Organizations

Musculoskeletal Committee of ICOH, member

Canadian & Ontario Public Health Associations, member

Canadian Society of International Health, member

College of Physicians and Surgeons of Ontario, registrant

International Society of Environmental Epidemiology, member

Ontario Medical Association, member

Royal College of Physicians and Surgeons of Canada, fellow in Occupational Medicine (1990) and Community Medicine (1992)

Employment History

Academic/Research

Sep 79-Dec 80 **Tutor**, Core III course "Issues in Community Health", MHSc Program, Division of Community Health, University of Toronto

1980-83 **Status Appointment**, Division of Community Health, Faculty of Medicine, University of Toronto

Jan-Dec 83 **Research Associate** to P. Niall Byrne, Faculty of Medicine, University of Toronto for contract with Health Promotion Directorate, Health and Welfare Canada, on Poverty, Health and Health Education

1992-98 **Status Appointment**, Division of Community Health, Faculty of Medicine, University of Toronto

1993 **Member**, Program Committee, Community Medicine Residency Program, McMaster University

Nov 93-Jun 97 **Research Fellow**, EcoResearch, Chair in Environmental Health, McMaster University

Jan 95-Dec 96 **Director**, Community Medicine Residency Program, McMaster University

Jul 97-Jan 99 **Acting Director of Research**, Institute for Work & Health

Feb 99- **Senior Scientist**, Workplace Studies, Institute for Work & Health

Community

Dec 75 & 76 **Nurse's Aide**, Matagami, Quebec

Aug 78-Aug 79 **Rotating Intern**, St. Joseph's Hospital, Toronto

Sep 79-Apr 80 **Physician**, Hassle Free Clinic

May-Oct 80 **Occupational Physician**, Leaside Medical Associates

Nov 80-Oct 83 **Staff Physician**, York Community Services. Hospital Appointments in Departments of Family Practice:

- Humber Memorial Hospital-Associate Staff
- Northwestern General Hospital-Courtesy Staff

Oct 83-Mar 84 **Medical Consultant**, Wellness for Seniors Health Kit - contract for Health Promotion Directorate, Health and Welfare Canada

Jun 84-Mar 85	**Occupational Physician**, Occupational Health Department, Division of Hygiene and Epidemiology, Ministry of Health, Nicaragua - CUSO placement
Apr 85-Dec 86	**Epidemiologist/Health Educator**, Pesticide Health and Safety Program, CARE Nicaragua
Jan-Jul 87	**Practicum Student**, Medical Advisory Service, Canadian Centre for Occupational Health and Safety
Jul 91-2001	**Occupational Physician (part-time)**, Lakeshore Area Multiservice Project (LAMP)

Consultations

Jul-Nov 80	**Co-Author**, city of Toronto Department of Public Health, report "The Chemical Society"
Feb 82	**Community Health Consultant**, Centro Sperimentale de Educazione Sanitaria, Perugia, Italy re popular participation in health.
Mar 87	**Development Consultant**, OXFAM Canada re a women's agricultural health and safety project in Nicaragua.
Jul 88-Jun 90	**Epidemiological Consultant**, with Dennis Willms & Elizabeth Lindsay. Scott-McKay-Bain Health Panel on Health Services in the Sioux Lookout Zone.
Oct 89-Jul 90	**Health Consultant**, Big Trout Lake Band re Community Health Development Plan.
Apr-May 92	**Evaluator**, Canadian Public Health Association. Bolivian Occupational Health and Safety Training Project.
1990-92	**Occupational Health Expert**, Public Health Coalition, Intervenor with Environmental Assessment Board for Ontario Hydro's 25 year Demand Supply Plan.
Nov 92-97	**Research Consultant**, Ontario Workers' Compensation Institute
Jan 93-Jul 93	**Public Health Consultant**, Hamilton-Wentworth Department of Public Health Services. Development of teaching modules in environmental health for community medicine residents
Oct 93-Jul 94	**Occupational Epidemiology Consultant**, Industrial Disease Standards Panel
Jan-Jul 94	**Environmental Epidemiologist**, Port Maitland Health Effects Study Committee
Oct-Jan 95	**Environmental Epidemiologist**, Halton Regional Health Unit
Mar-Jun 97	**Medical Consultant in Environmental Health**, Ontario Ministry of Health

Oct 98-00 **Medical/Environmental Health Consultant**, Bio-Regional Health Effects Division, Health Canada

Advisory Committees

1982-83 **Member**, Community Health Centre/Health Service Organization Evaluation Committee

Jun 87-Jun 89 **Member**, Ontario Pesticide Advisory Committee (OPAC) to Minister of the Environment

Scholarly & Professional Activities

Grant Committees

1987-89 OPAC reviewed and awarded pesticide research grants

1993-94 St. Lawrence Health Effects Program/FRSQ

1995 National Health Research and Development Program: Environmental and Occupational Health

2001-02 Canadian Institutes of Health Research: Public, Community and Population Health

Journal Referee

1992- New Solutions

1995- Chronic Diseases in Canada

1996- American Journal of Industrial Medicine

1996- Canadian Journal of Public Health

1998- Social Science and Medicine

1998- Journal of Environmental Management

1999- Canadian Medical Association Journal

1999- American Journal of Epidemiology

2001- Journal of Rheumatology

BioMed Central, e-journal

Health Reports

External Grant Reviews

1987-98 Alberta Occupational Health and Safety

1988- National Health Research and Development Program

1996-99 Great Lakes Research Consortium

1997- Medical Research Council/Canadian Institutes of Health Research

1999- Institut de Recherche en Santé et en Sécurité du Travail du Québec

1999- Northern Contaminants Program

1999- Foutes de Recherche en Santé du Québec

1999- Workplace Safety and Insurance Board

1999- Social Sciences and Humanities Research Council

Other

1988-90 **Member**, Chile Project Advisory Committee, CPHA

1989 **Representative**, Environmental and Occupational Health Division, to Planning Committee for OPHA Annual Conference in Hamilton, Nov 1989

1995 - **Member**, Expert Working Group, Pesticide Exposure Study, Health Canada

1999 - **Member**, Epidemiology Advisory Panel, NSERC Strategic Grant on Exposure Biomarkers for Drinking Water DBPs

1999 **Member**, Expert Review Panel on Inhalable/Respirable Particulates for CRESTECH/NERAM (Network on Risk Assessment and Management)

1999 - **Member**, MSF Aral Sea Area Operational Research Advisory Committee

Areas of Interest

Descriptive, etiological and intervention research, education and policy development re:

Work-related soft tissue musculoskeletal disorders

Work stress

Pesticide impacts on human health and ecosystems

Human health indicators for bio-physical environmental exposures

Environmental and occupational reproductive risks

Courses Taught

Md Undergraduate Program - Mcmaster

Jan 88-Mar 88 **Co-tutor**, Unit 5

Sep 87-Dec 90 **Community health preceptor**, Unit 1

1992-98 **Community health day** facilitator & panel member

Graduate Programs - Mcmaster

Sep-Dec 88 **Co-tutor**. MS 771, Population Health

1991- **Tutor in Epidemiology**, Diploma in Occupational Health

1992-98 Resource Person,. MS 722, Fundamentals of Health and Development. Session on Environment & Health

1992- **Resource Person**, Community Medicine Residency Program seminars

1994-98 **Tutor**, MS 730 of HRM (Health Research Methods) Program, MSc.

1994- **Tutor**, MS 721of HRM, Teaching Health Unit group

1995 **Resource person**, DME/HRM 709 re Interdisciplinary Investigation of Hamilton Harbour Ecosystem

1996- **Tutor**, MS 751(Observational Designs) of DME/HRM, MSc.

Other

Sep-Dec 75 **Instructor**, Industrial Hygiene I. Humber College of Applied Arts and Technology.

1985-86 **Planner, Materials Developer, Facilitator and Evaluator**, Workshops in pesticide health and safety for rural health professionals, inspectors and teachers. CARE Nicaragua and Ministries of Health, Education, Labour and Agriculture.

Jun 87-Dec 88 **Module Developer and Evaluator**, Training project in environmental and occupational health for public health personnel. Hamilton Wentworth Teaching Health Unit/Department of Public Health Services.

Nov 94 **Workshop Designer & Speaker**, Environmental risk assessment.

Summer 95 **Planning Group Member**, MS 751 of DME. Observational Designs

1995-88 **Course Developer and Core Faculty**, Diploma in Environmental Health

1996 **Session Leader**, Reproductive epidemiology in environmental epidemiology course, Division of Community Health, University of Toronto

May 1997 **Workshop Designer and Leader**, Environmental influences on pre-conceptional health, Preconceptional Health Conference

1997-99 **Instructor in Epidemiology**, Advanced principles of toxicology, University of Guelph

Supervisorships

Undergraduate

Sep-Apr 94 Alison Brodie, 4th year Geography research course on respiratory health among Hamilton Homeside residents. Co-supervisor with John Eyles.

Sep 01-Sep 02 Dwayne Van Eerd, Toronto Star/SONG Research project.

MSc Students

Sept-Dec 94 Jennie James, Environmental hazards and primary care. Co-supervisor with John Eyles.

Jun-Dec 95 Mario Fuentes, Reproductive outcomes and environmental exposures. DME research assistantship.

MHSc Students (University of Toronto)

May-Aug 92 one Y1 re Health Promotion in the Small Workplace

Sept-Dec 95 Lisa Belzac, project supervisor for Environmental Epidemiology course

Apr-July 00 Lori Greco, Health Promotion re: Workplace Intervention Evaluation

Community Medicine Residents

Full time placements at Lakeshore Area Multiservice Project (LAMP)

Apr-Jun 92 one R1

Oct 92-Jan 93 one R4 - David Stieb, re: Program Evaluation

Jan-Mar 93 one R3

Jul 93-Jul 94 Richard Heinzl R1, re: Environmental Health Module for Residents

[In addition two sets of Community Medicine Residents from University of Toronto as part of Occupational and Environmental Health Block]

Feb-Sept 94 Maureen Baikie R3, re: DME Thesis on PCB's and Fertility

Aug 94-Jun 95 Ian Scott R2, re: Community Environmental Health Assessment

Oct 95-Mar 96 Nashila Mohammed R3, re: Evaluation of a Community Lead Education Program

Oct 99-Dec 00 Karen Lee, R4, re: Workplace Psychosocial Factors and Cardiovascular Disease

Thesis Committees

MSc Theses

Co-Supervisor:

What is the relationship between Great Lakes fish consumption and nutritional status?

Elaine Murkin, University of Guelph, Community Nutrition (1996-1998)

Supervisory Committee Member:

Prevalence of risk factors for chlamydia trachomatis infection among Latin American women of Hamilton-Wentworth. Mario Fuentes, McMaster University, Clinical Epidemiology and Biostatistics (1996-1997)

Influence of working under deadlines in the newspaper industry on the risk of upper extremity WMSDs. Lisa Beech-Hawley, University of Waterloo, Kinesiology (1996-1998)

Predictors of Great Lakes fish consumption among fishers in Ontario areas of concern. Howard Shapiro, University of Toronto, Community Health (1998-)

Examiner for Theses Defences:

Internal:

Perceiving health and the environment: connections, conceptions and cognitions. Jennie James, McMaster University, School of Geography and Geology (1996)

Physician utilization in Quebec 1987 and 1992-3: the impact of regionalization in a cost-constrained climate. Kathleen J. Wilson, McMaster University, School of Geography and Geology (1996)

External:

Genetic Polymorphisms in Ah Receptor and Cytochrome P450 Drug-Metabolizing Enzymes in relation to Estradiol Metabolism and Breast Cancer Susceptibility. Maria Shuk Mun Lam, University of Toronto, Pharmacology (2000)

Negotiating successful return to work: Perspectives of nurses with low back pain. Anna Ballon, University of Toronto, Rehabilitation Science (2000)

PhD Theses

Supervisory Committee Member:

A follow-up study of workers with acute soft tissue injuries using the Ontario Workers= Compensation Board database. Hua Wang, University of Toronto, Exercise Sciences (1996-00)

Towards better prevention of work-related musculoskeletal disorders in Ontario: an exploration of the process and outcomes of a search conference on a contentious issue. Michael F.D. Polanyi, York University, Faculty of Environmental Studies (1997-99)

A nested case-controlled study of the reproductive effects of ionizing radiation. Monica Bienefeld, University of Toronto, Community Health (1998-)

Assuming that language has depth, how deep are the Great Lakes? Adele Iannantuono, McMaster University, School of Geography and Geology (1998 -)

The Canadian healthy communities project. Colin McMullan, McMaster University, School of Geography and Geology (1998 -)

Social Capital and Environmental Risk: Understanding individual and community responses to adverse air quality in Hamilton-Wentworth. Sarah Wakefield, McMaster University, School of Geography and Geology (1998-)

From research transfer to research transformation: A manufacturing workplace intervention study.

Dee Kramer, University of Toronto, Department of Theory and Policy Studies in Education (2000-)

Examiner for Comprehensive Examinations:

Jamie Baxter (1995), Adele Iannouatou (1996) and Sarah Wakefield (1999) Special area of risk and environmental health, all at McMaster University, School of Geography and Geology

Examiner for Dissertation Defence:

The search for a landfill site in an age of risk: the role of trust, risk and the environment. Harris Ali, McMaster University (Sociology) (1996)

External Examiner:

The development and validation of a pesticide dose prediction model. Shelley Harris. University of Toronto, Epidemiology (1999)

Post-Doctoral Fellowship

Supervisor:

Musculoskeletal disorders, work environment and health. Mustard Fellow with the Institute for Work & Health. Mieke Koehoorn (Dec 1998 - June 2001)

Education Funding

Funded

Orris P, Cole DC, Kirkland K, Gibson B. Great Lakes Environmental Scholars Program. (US Agency for Toxic Substances and Disease Registry, US$31,742; 1995)

Eyles J, Cole DC, Environmental Risk - unpacking the black box. A Continuing Education Symposium. (Ontario Ministry of Health 1995 $20,000)

Voorberg N, Cole DC, Hunter W, Scott I. Homeside community environmental health project. (Health of the Public Project 1995-96, $10,000)

Valaitis R, Cole DC, Chambers LW, O'Mara L, Rideout L, Thomas H, Turpie I, VanBerkel C, Ehrlich A. The development of a CD-ROM computer-assisted instruction program: community action skills for staff in community health agencies and health sciences students. (Health of the Public Project & McMaster University on Teaching and Learning 1995-96 $16,220) (Available now through CPHA)

Elliot SJ, Eyles J, Cole DC. Internet (distance) learning: pilot module for the Environmental Health Program. (McMaster University Committee on Teaching and Learning, $3,600)

Research Funding

Funded

Cole DC, Carpio F, Crissman C, Antle J, Wagonet J: Health effects of pesticide use in

Ecuadorian potato production. (Rockefeller Foundation Health & Agriculture Divisions 1993 supplement $US 60,000 on base of 1991-93 US$ 180,000)

Kearney J, Cole DC et al. Anglers' pilot exposure assessment study. (Health and Welfare Canada, Health Protection Branch 1992-94 about $250,000)

Sinclair SJ, Cole DC, Frank JW et al. Early claimant cohort study. (Ontario Workers' Compensation Institute and Workers' Compensation Board of Ontario 1993-95 about $200,000)

Dodin S, Lebel G, Lemay A, Villeneuve M, Maheux R, Berube S, Cole DC, Hughes E, Ferron L: Organochlorés et endometriose: une étude pilote. (Health Canada, Health Protection Branch 1994-95 $99,778)

Pengelly LD, Cole DC. Indicators of air quality in areas of concern: Pilot Study. (Health Canada, Health Protection Branch 1994-95 $40,000)

Riedel D, Kraft D, Cole DC, Owen S et al. High risk groups' fish and wildlife nutrition project. (Health Canada, Health Protection Branch 1995-96 $168,700)

Kearney K, Cole DC. Exposure assessment study development. (Health Canada, Health Protection Branch 1995-96 $14,000)

Pengelly LD, Silverman F, Cole DC, Eyles J. Indicators of air quality in areas of concern: implementation of criteria developed from pilot study. (Health Canada 1995-96 $73,640)

Wells R, Shannon HS, Cole DC, Norman R; Electromyography protocols for measurement of exposure in VDT operators. (Johns Hopkins University, Centre for VDT=s and Health 1996-97 $67,608)

Cole DC, Collins J, Mugga H, Foster W et al: Time to pregnancy and environmental exposures. (Health Canada and FL Johnson Fund 1996-97 $40,000)

Cole DC, Shannon HS, Beaton DE et al. Phase II: RSI Watch. Toronto Star/Southern Ontario Newspaper Guild ($75,000); Institute for Work & Health 1996-98 (internal budget: $75,000)

Cole DC, Sheeshka J, Kearney J, Eyles J et al: Great Lakes fish eaters project: dietary survey and assessment of potential health risks and benefits. (Health Canada 1996-97 $227,500; 1997-98 $169,000; 1998-99 $69,000)

Cole DC, Sheeshka J, Kraft D, Owens S, Eyles J et al: Sport fish and wildlife study in areas of concern. (Health Canada 1996-97 $145,000; 1997-98 $108,000;1998-99 $95,000)

Shannon H, Cole DC, Eyles J, Scott F, Goel V, Mondloch M. Work and Health: An analysis using data from the National Population Health Survey. (NHRDP, Health Canada 1997-98 $34,726)

Elliott S, Cole DC et al. Community action on air quality (Hamilton Community Foundation 1998-00 $35,000)

Crissman C, Cole DC, Barrera V, Berti P. Human Health and Changes in Potato Production Technology in the Highland Ecuadorian Agro-Ecosystem. (International Development Research Centre 1998-01 $149,740)

Frank JW et al including Cole DC, Ontario, Quebec and Manitoba Project Working Groups. Evidence-based tools for return-to-work: WorkReady II. (HEALNet 1998-99 $130,000)

Wells, RW, Norman R, Frazer M, Neumann P, Shannon HS, Kerr M, Cole DC. Evaluating Workplace Interventions. (HEALNet 1998-99 $55,225)

Lavis J, Cole DC, Jadad A, Shannon HS, Woodward C. Conceptualization of evidence in the workplace (HEALNet, 1998-99 $10,000) and an analysis of primary stakeholders perspectives of Ahealthy workplaces@. (HEALNet 1998-99 $25,000)

Shannon HS, Eakin J, Kerr M, Cole DC, Robson L. Workplace Performance Measures. (HEALNet 1998-99 $55,000)

Cole DC, Hogg-Johnson S et al. Phase III: STOP RSI. Toronto Star/Southern Ontario Newspaper Guild (1999-00 $144,000)

Beaton DE, Cole DC, Hogg-Johnson S, Bombardier C. A multi-pronged approach to the classification of WMSD in VDT workers. (Center for VDT and Health Research, The Johns Hopkins University 1999-00 US$ 41,405)

Wells R, Cole DC, Norman R, Shannon HS, Hogg-Johnson S. Precision and responsiveness of physical exposure measures in an office environment (Center for VTD and Health Research, Johns Hopkins University 1999-00 CAN$ 182,150)

Koehoorn M, Cole DC, Hertzman C. Risk factors associated with work-related musculoskeletal disorders and burden of musculoskeletal disorders among a cohort of B.C. health care workers (Workers Compensation Board of British Columbia 1999-00 $46,033)

Lewchuk W, Robertson D, Kerr M, Cole DC, Landsbergis PA, Schall PL, Haimer AT, Sullivan TJ. A study of work organization and health in the transportation sector. (Workplace Safety & Insurance Board 1999-01 $300,000)

Strong S, Cole DC, Gibson E, Kaplan R, Shannon HS, Sinclair S, Clarke J. Assessment of a person=s ability to function at work. (Workplace Safety & Insurance Board 1999-01 $95,000 and Medical Research Council 1999-01 $421,000)

Cole DC, Wainman B, Younglai E, Harper P, Ryan J, Weber JP, Arts M. Contaminant and mechanistic correlates of time to their newborn (Toxic Substances Research Initiative, Health and Environment Canada 1999-01 $186,000)

Cole DC, Hogg-Johnson S, Shannon HS, Hyatt D, Beaton DE, Wells R. WMSDs: Evaluating interventions in office workers. NIOSH (U.S. National Institute for Occupational Health and Safety & National Institutes of Health 1999-02 US$396,354)

Robson L, Shannon HS, Cole DC, Kerr MS, Eakin J, Polanyi MF, Brooker A-S, Sale J, Ibrahim SA. Collaborative research-workplace-stakeholder development of a Ahealthy workplace@ performance assessment tool. (HEALNet 1999-02 $203,314)

Norman R, Wells R, Neumann P, Cole DC, Shannon HS, Kerr MS. Assessment of the effectiveness of evidence-based ergonomic decision in workplaces on prevention of work-related musculoskeletal disorders. (HEALNet 1999-02 $274,000)

Stock S, Baril R, Durand M-J, Rossignol M, Cole DC, Wells R, Lau F, Moehr J, Guzman J. Developing and evaluating tools to facilitate evidence-based decisions on return to work measures in the electric and electronic sectors. (HEALNet 1999-02 $258,745)

[Lemieux-Charles et al CCHSA/HEALNet grant]

Wells R, Cole DC, Brawley L, Frazer M, Kerr MS, Kerton R, Neumann P, Norman R. Evaluation of participatory ergonomic interventions in large and small industry. (Workplace Safety and Insurance Board 1999-03 $299,431)

Koehoorn M, Cole DC, Hertzman C, Ostry A, Ibrahim S. Studying the health of health care workers: Focus on long-term disability claims. (CIHR, 2000-02 $92,006)

Koehoorn M, Cole DC, Hertzman C. Health care utilization and costs associated with musculoskeletal disorders among health care workers. (B.C. Workers' Compensation Board, 2000-02 $49,000)

Koehoorn M, Hertzman C, Cole DC. Individual, biomechanical and work organization factors associated with musculoskeletal disorders among a cohort of health care workers . (B.C. Workers' Compensation Board, 2000-02 $7,672)

Loisel P, Arsenault B, Baril R, Berthelette D, Bombardier C, Brun J-P, Cole DC, Cooper J, Clermont D, Durand M-J. Training new investigators in work disability prevention. CIHR, applied, 2002-03 $300,000)

Prain G, Cole DC. Urban agriculture-health impact assessment options. (Canadian International Development Agency, applied, 2002-05 $150,000)

Lifetime Publications

Peer-Reviewed

Journal Articles

Cole DC, Murray DL, McConnell R, Pacheco Anton F. Pesticide illness surveillance: The Nicaraguan experience. **PAHO Bulletin** 1988;22(2):119-132.

Cole DC, Heath B, Chase R, Cherry C. Local partnerships for healthy workplaces and communities - an Ontario experience. **New Solutions** 1992;2(4):22-25.

Willms DG, Lange P, Bayfield D, Beardy M, Lindsay EA, Cole DC, Johnson NA. A lament by women for " the people, the land" [Nishnawbi-Aski Nation]: an experience of loss. **Can J Public Health** 1992;83(3):331-334.

Chase RM, Liss GM, Cole DC, Heath B. Toxic health effects including reversible macrothrombocytosis in workers exposed to asphalt fumes. **Am J Ind Med** 1994;25:279-289.

Crissman C, Cole DC, Carpio F. Pesticide use and farm worker health in Ecuadorian potato production. **Am J Agric Econ** 76 (Aug 1994):593-597.

Hudak PL, Amadio PC, Bombardier C and the Upper Extremity Collaborative Group (includes Cole DC). Development of an upper extremity outcome measure: the DASH (Disabilities of the Arm, Shoulder and Hand). **Am J Ind Med** 1996;29:602-608.

Cole DC, Hudak PL. Understanding prognosis of non-specific work related musculoskeletal disorders of the neck and upper extremity. **Am J Ind Med** 1996;29:657-668.

Stock SR, Cole DC, Tugwell P, Streiner D. Measuring functional status in workers with overuse disorders of the neck and upper limb: a review of the relevance and comprehensiveness of existing instruments. **Am J Ind Med** 1996;29(6):679-688.

George L, Hunter W, Scott FE, Siracusa L, Buffett C, Ostofi G, Zinkewich R, Cole DC. The mercury emergency in Hamilton, Sept 1993. **J Environ Health** Apr 1996;58(8):6-10.

Hudak PL, Cole DC, Haines AT. Understanding prognosis to improve rehabilitation: the case of lateral elbow pain. **Arch Phys Med & Rehab** 1996;77:586-593.

George L, Scott FE, Cole DC, Siracusa L, Buffet C, Hunter W, Zinkewich R. The mercury emergency and Hamilton school children: A follow-up analysis. **Can J Public Health** 1996;87(4):224-226.

Cole DC, Tarasuk V, Frank JW, Eyles J. Research responses to outbreaks of concern about local environments. **Arch Environ Health** 1996;51(5):352-358.

Cavan KR, Gibson BL, Cole DC, Riedel D. Fish Consumption by Vietnamese women immigrants: a comparison of methods. **Arch Environ Health** 1996;51(6):452-457.

Cole DC, Kearney JP. Blood cadmium, game consumption and tobacco smoking in southern Ontario anglers and hunters. **Can J Public Health** 1997;88(1):44-46.

Cole DC, Kearney J, Ryan JJ, Gilman AP. Plasma levels and profiles of dioxin and dioxin-like compounds in Ontario Great Lakes anglers. **Chemosphere** 1997;34/5-7:1401-1409.

Cole DC, Carpio F, Julian J, Leon N, Carbotte R, De Almeida H. Neurobehavioural outcomes among farm and non-farm rural Ecuadorians. **Neurotoxicol & Teratol** 1997;19(4):277-286.

Ross N, Eyles J, Cole DC, Iannantuono A. The ecosystem health metaphor in science and policy. **Canadian Geographer** 1997;41(2):114-127.

Cole DC, Carpio F, Julian J, Leon N. Dermatitis in Ecuadorean farm workers. **Contact Dermatitis - (Environmental and Occupational Dermatitis)** 1997;37:1-8.

Polanyi MFD, Cole DC, Beaton DE, et al. Upper limb work-related musculoskeletal disorders among newspaper employees: cross-sectional survey results. **Am J Ind Med** 1997;32:620-628.

Jerrett M, Eyles J, Cole DC, Reader S. Environmental equity in Canada: an empirical investigation into the income distribution of pollution in Ontario. **Environment and Planning** A 1997, 29, 1777-1800.

Frank JW, Sinclair S, Hogg-Johnson SA, Shannon HS, Bombarier C, Beaton DE, Cole DC Preventing disability from work-related low-back pain: new evidence gives new hope - if we can just get all the players onside. **CMAJ** 1998;158(12): 1625-1631.

Antle JM, Cole DC, Crissman CC. Further evidence on pesticides, productivity and farmer health: potato production in Ecuador. **Agriculture Economics** 1998;18:199-207.

Jerrett M, Eyles J, Cole DC. Socioeconomic and environmental covariates of premature mortality in Ontario. **Soc Sci Med** 1998;47(1):33-49.

Cole DC, Eyles J, Gibson BL. Indicators of human health in ecosystems: what do we measure? **Sci Total Environ** 1998;24:1-3.

Cole DC, Carpio F, Jullian J, Leon N. Assessment of peripheral nerve function in an Ecuadorean rural population exposed to pesticides. **J Toxicol Environ Health** 1998;55/2:77-91.

Cole DC, Eyles J, Gibson BL, Ross N. Links between humans and ecosystems: the implications of framing for health promotion strategies. **Health Promotion International** 1998;14(1):65-72.

Bell W, Yassi A, Cole DC. On PMW and two-stroke engines: health and environmental alert. **Canadian Family Physician** 1998;44:1757-2028.

Hudak PL, Cole DC, Frank JW. Perspectives on prognosis of soft tissue musculoskeletal disorders. **Int J Rehabilitation Research** 1998;21(1):29-40.

Cole DC, Pengelly LD, Eyles J, Stieb DM, Hustler R. Consulting the community for environmental health indicator development: the case of air quality. **Health Promotion International** 1999;14(2):145-154.

Kearney JP, Cole DC, Ferron LA, Weber JP. Blood PCB, p,p'-DDE, mirex, mercury and lead levels in Great Lakes fish and waterfowl consumed in two Ontario communities. **Environ Res** 1999, Section A 80, S138-S149.

Cole DC, Upshur R, Gibson BL. Environmental burden of human illness: scoping the problem. **Alternatives** Summer 1999;25(3): 26-32

Elliott SJ, Cole DC, Krueger P, Voorberg N, Wakefield S. The power of perception: health risk attributed to air pollution in an urban industrial neighbourhood. **Risk Anal** 1999;19(4).

Arbuckle T, Schrader S, Cole DC, Hall C, Bancej C, Turner L, Claman P. 2,4-D Residues in semen of Ontario farmers. **Reprod Toxicol** 1999;13(6):421-429.

Davis AM, Beaton DE, Hudak P, Amadio P, Bombardier C, Cole DC, Hawker G, Katz JN, Makela M, Marx RG, Pennett L, Wright JG. Measuring disability of the upper extremity: a rational supporting the use of a regional outcome measure. **J Hand Ther** 1999;12(4):269-274.

Cole DC, Carpio F, León N. Economic burden of illness from pesticide poisonings in highland Ecuador. **Pan American Review of Public Health** 2000;8(3):196-201.

Beaton DE, Cole DC, Manno M, Bombardier C, Hogg-Johnson S, Shannon HS. Describing the burden of upper extremity musculoskeletal disorders in newspaper workers: What difference do case definitions make? **J Occup Rehab** 2000;10(1):39-53.

Lee K, Cole DC. Workplace health promotion in Ontario public health units: Results of a survey of attendees of the 2000 Health Promotion Ontario Spring Conference focusing on workplace health promotion. **PHERO** (Public Health & Epidemiology Report Ontario);11(8):200-205.

Anger WK, Liang Y-X, Nell V, Kang S-K, Cole DC, Bazylewicz-Walczak B, Rohlman DS, Sizemore OJ. Lessons learned: 15 years of the WHO-NCTB. **Neurotoxicology** 2000;21:837-846.

Brooker A-S, Cole DC, Hogg-Johnson S, Smith J, Frank JW, and the Early Claimant Cohort Prognostic Modeling Group. Modified work: Prevalence and characteristics in a sample of workers with soft tissue injuries. **JOEM** 2001;43(3):276-284.

Swift M, Cole DC, Beaton DE, Manno M, Worksite Upper Extremity Group. Health care utilization and workplace interventions for neck and upper limb problems among newspaper workers. **JOEM** 2001;42(3):265-275.

Mondloch MV, Cole DC, Frank JW. Does how you do depend upon how you think you'll do?: a structured review of the evidence for relation between patients' recovery expectations and outcomes. **CMAJ** 2001;165(1):174-179.

Ibrahim SA, Cole DC, Scott F, Shannon HS, Eyles J. Job strain and self-reported health among working women and men: An analysis of the 1994/5 Canadian National Population Health survey **Women & Health** 2001;33(2):105-124.

Cole DC, Ibrahim SA, Shannon HS, Scott F, Eyles J. Work correlates of back problems and activity restriction due to musculoskeletal disorders in the Canadian National Population Health Survey (NPHS) 1994/95 Data. **J Occup Environ Med** 2001;58:728-734.

Wells R, Bao S, Norman R, Shannon HS, Cole DC, Woo H. Measurement of work exposure in the upper limbs of VDT operators using surface electromyography: responsiveness to office tasks and input devices and resulting recommendations. Accepted: **Journal of Electromyography and Kinesiology**

Wells R, Norman R, Shannon HS, Cole DC, Woo H, Bao S. Measurement of work exposure in the upper limbs of VDT operators using electromyography: electrode sites, normalization and within and between day reliability. Accepted: **Journal of Electromyography and Kinesiology**

Cole DC, Mondloch MV, ECC Prognostic Modeling Group. Listening to injured workers: how recovery expectations predict outcomes? Accepted: **CMAJ**

Sanborn M, Abelsohn A, Cole DC, Weir E. Identifying and managing the health effects of toxic environmental exposures: pesticides. Accepted: **CMAJ**

Cole DC, Wells RP. Interventions for musculoskeletal disorders in computer intense office work: a framework for evalutaion. Accepted: **Work & Stress.**

Cole DC, Sheeshka J, Kearney J, Scott F, Ferron LA, Weber J-P, and the Fish and Wildlife Nutrition Project. Dietary intakes and plasma organochlorine contiminant levels among Great Lakes fish eaters. Accepted: **Arch Environ Health.**

Arcbuckle TE, Burnett R, Cole DC, Teschke K, Bancej C, Zhang J. Predictors of herbicide exposure in farm applicators. Accepted: **International Archives Occup and Environ Health**

Driedger M, Eyles J, Elliott S, Cole DC. Constructing scientific authorities: Issue framing of chlorinated disinfection by-products in public health. Accepted: **Risk Analysis**

Submitted for Publication:

Smith J, Tarasuk V, Shannon HS, Ferrier, ECC Prognostic Modeling Group (includes Cole DC). Prognosis of musculoskeletal disorders: effects of legitimacy and job vulnerability. To: **J Occup Health Psychol**

Sanborn MD, Scott FE, Cole DC. Environmental health concerns and information needs of family medicine residents. To: **Medical Education**

Hogg-Johnson S, Cole DC, Early Claimant Cohort Design Group, Prognostic Modeling Workgroup. Early prognostic factors for duration on benefits among workers with compensated occupational soft tissue injuries. To: **Occup Environ Med**

Cole DC, Ibrahim S, Shannon HS, Scott F, Eyles. Work and life stressors an psychological distress in the Canadian working population: a structural equation modeling approach to analysis of the 1994 National Population Health Survey. To: **Chronic Diseases in Canada**.

Kearney JP, Cole DC. Great Lakes and inland sport fish consumption by licensed anglers in two Ontario communities. To: **Journal of Great Lakes Research**

Breslin FC, Ibrahim S, Hepburn CG, Cole DC. Sense of coherence and emotional distress: Extent and type of construct overlap. To: **Psychological Assessment.**

Wang H, Hogg-Johnson S, Cole DC, Thomas S, Corey P. Prognostic groups for lost-time soft tissue claimants based on Ontario workers= compensation data. To: **Am J Public Health**.

Proceedings of Meetings

Cole DC, Stock SR, Gibson ES. Workplace based interventions to reduce overuse disorders of the neck and upper extremity: an epidemiologic review. 25th Annual Conference of the Human Factors Association of Canada - 1992. Hamilton, Ontario. pp 263-269.

Cole DC, Eyles J. Combining qualitative and quantitative approaches to assessing impacts of environments on human health and well-being in local community studies. In: Johnson BL, Xintaras C, Andrews JS (eds). Hazardous Waste: Impacts on Human and Ecological Health. Proceedings of the 2nd International Congress, Atlanta, Georgia, US, 5-8 Jun 1995. Princeton, N.J.: Princeton Scientific Publishing Co., Inc. 1997.

Cole DC, Beaton DE. Upper extremity work-related musculoskeletal disorders: the long road to guidelines. In: Harris J (ed). Occupational Medicine in Managed Care and Integrated Delivery Systems. American College of Occupational and Environmental Medicine (1998).

Cole DC. Human health in agroecosystem health. In: Blair R, Rajamahendran R, Mohan M, Stephens LS, Yang MY (eds). Canadian Society of Animal Science. Proceedings of Annual Meeting. 5-8 Jul 1998, Vancouver, B.C.

Robson LS, Polanyi MF, Kerr MS, Shannon HS, Eakin JM, Brooker A-S, Cole DC. What is a ›healthy workplace?= In: Vink P, Koningsvel EAP, Dhondt S (eds). Human Factors in Organizational Design and Management VI. Proceedings of the 6th International Conference on Human Factors in Organizational Design and Management. The Hague, The Netherlands, 19-22 Aug 1998, North-Holland: Elsevier Science:539-544.

Wells R, Cole DC and the Worksite Upper Extremity Research Group. Intervention in computer intense work. In: Sandsjö L, Kadefors R (eds). Prevention of Muscle Disorders in Computer Users: Scientific Basis and Recommendations. The 2nd PROCID (Prevention of Muscle Disorders in Operation of Computer Input Devices) Symposium. National Institute for Working Life/West, Göteborg, Sweden , 8-10 March 2001:99-125.

Village J, Cole DC. Musculoskeletal disorders and psychosocial factors among newspaper and commercial print workers. SELF-ACE 2001 Conference - Ergonomics for changing work. Vol. 5. Musculoskeletal disorders: understanding and intervention, Oct 2001.

Other

Cole DC. Evaluation of early intervention for neck and upper extremity repetitive strains by human factors specialists and occupational therapists. MSc thesis. McMaster University, Hamilton. June 1991. 278 pp.

Kearney J, Cole DC, Haines D. Report on the Great Lakes anglers' pilot exposure assessment study. Health Canada. May 1995.

Sinclair S, Erdeljan SE, Cole DC, Frank JW, Hogg-Johnson S, Kralj B, Lee D, Mondloch MV. Evaluation of the community clinic program in the rehabilitation of workers with soft tissue injury. Report to the Ontario Workers= Compensation Board. June 1995.

Eyles J, Cole DC. Human health in ecosystem health: issues of meaning and measurement. Report submitted to the Scientific Advisory Board, International Joint Commission. Windsor. May 1996.

Sanborn M, Cole DC. Environmental health in family medicine: pesticide module. Environmental Health in Family Medicine Curriculum Development Project, Ontario College of Family Physicians and the Health Professionals Task Force of the International Joint Commission. Toronto. June 2000.

Not Peer-Reviewed

Contributions to Books

Cole DC. Ensuring safe use of pesticides in developing countries. In: ReVelle P, ReVelle C (eds). The global environment securing a sustainable future. Boston, London: Jones & Bartlett 1992.

All in: Crissman CC, Antle J, Capalbo S (eds). Economic, environmental and health tradeoffs in agriculture: pesticides and the sustainability of Andean potato production. Dordrecht/Boston/London: Kluwer Academic Publishers, "Natural Resource Management and Policy" Series 1998, 281 pp

Cole DC, Carpio F, Leon N. Chapter 4: Conceptual and methodological aspects of investigating the health impacts of agricultural pesticides: 65-81.

Cole DC, Carpio F, Leon N, Merino R, Julian J. Chapter 9: Health impacts of pesticide use in Carchi farm populations: 209-230.

Antle JM, Cole DC, Crissman CC. Chapter 10: The role of pesticides in farm productivity and farmer health: 231-241.

Antle JM, Capalbo SM, Cole DC, Crissman CC, Wagenet RJ. Chapter 11: Integrated simulation model and analysis of economic, environmental and health tradeoffs in the Carachi potato-pasture production system: 243-267.

Frank JW, Guzman J, Cole DC. Work-ready: What works and what doesn=t work to prevent disability secondary to soft tissue injuries. Institute for Work & Health for the HEALNet Work-Ready Research Group Dec 1998.

Both in: T. Sullivan (Ed) Injury and the New World of Work. Vancouver: University of British Columbia Press 2000.

Chung J, Cole DC, Clarke J. Chapter 4, Women, work and injury.

Hogg-Johnson S, Cole DC, Côté P, Frank J. Chapter 9, Rehabilitation and return to work: optimal phasing and staging of interventions following soft-tissue injuries.

Working/Occasional Papers

Cole DC. Risk assessment workshop. McMaster University, Environmental Health Program, Working Paper Series 3, 1995. 104 pp.

Cole DC, Shannon HS, Beaton D. The process of recovery from work-related soft tissue injuries: a discussion paper. IWH Working Paper #32 (1995)

Brooker A-S, Frank JW, Cole DC, Shannon HS. Occupational health monitoring: A framework for considering different types of systems (& some evidence for their effectiveness)

IWH Working Paper #51 (1997)

Scott F, Ibrahim SA, Shannon HS, Cole DC, Eyles J, Goel V. Canadian working women: job stress and self-reported health, an analysis of the1994-5 national population. IWH Working Paper #66 (1998)

Jonathan Smith, Valerie Tarasuk, Harry Shannon, Sue Ferrier. Prognosis of muscoloskeletal disorders: effects of legitimacy and job vulnerability. IWH Working Paper #67.

Clarke J, Chung J, Cole DC, Hogg-Johnson S, Haidar and the ECC Prognosis Working Group. Gender and benefit duration in lost time work-related soft tissue disorders: relationships with work and social factors. IWH Working Paper #85

Smith JM, Cole DC, Ibrahim S. Job satisfaction, pain intensity, and absenteeism in work-related upper extremity musculoskeletal disorders: An investigation using path analysis. IWH Working Paper #112.

Cole DC, Ibrahim SA, Shannon HS, Scott F, Eyles J. Work stressors and psychological distress in the Canadian working population: a structural equation modelling approach to analysis of the 1994 National Population Health Survey. IWH Working Paper #134

Van Eerd D, Beaton DE, Cole DC, Lucas J, Hogg-Johnson S, Bombardier C. Existing classification systems for upper-limb work-related musculoskeletal disorders: A review of the literature. IWH Working Paper # 141

Hogg-Johnson S, Ibrahim S, Beaton DE, Cole DC, Van Eerd D, Bombardier C. Searching for the syndromes and configuring the whole: a data-driven approach to the classification of musculoskeletal disorders of the upper extremity. IWH Working Paper # 142

Hogg-Johnson S, Beaton DE, Cole DC, Ibrahim S Van Eerd D, Bombardier C. Combining expert judgement and factor analysis to classify work related musculoskeletal disorders of the upper extremity. IWH Working Paper # 143

Beaton DE, Bombardier C, Cole DC, Hogg-Johnson S, Van Eerd, D and the clinical expert group. Classification of work-related musculoskeletal disorders of the upper limb: A pattern-recognition. IWH Working Paper # 144.

Beaton DE, Cole DC, Hogg-Johnson S,Van Eerd D, Bombardier C, and the clinical expert group. Reliability and validity of a classification system for upper limb musculoskeletal disorders. IWH Working Paper # 145.

Cole DC, Beaton DE, VanEerd D, Hogg-Johnson S, Ibrahim S, Bombardier C. A comparison of the classification systems for neck and upper limb pain developed using different methodological approaches on the same set of data.. IWH Working Paper # 146.

Keir PJ, Wells RP, Cole DC, Manno M, Beaton DE, Grossman J. Surface EMG as a diagnostic aid for neck and upper-limb musculoskeletal disorders. IWH Working Paper #152.

Breslin FC, Ibrahim S, Hepburn CG, Cole DC. Sense of coherence and emotional distress: Extent and type of construct overlap. IWH Working Paper #155.

Hogg-Johnson S, Manno M, Cole DC and the Worksite Upper Extremity Research Group.

Reporting Work-Related Musculoskeletal Disorders to the Workplace: factors associated with reporting among newspaper workers. IWH Working Paper # 173. (2001)

Cole DC, Manno M, Beaton D, Swift M. Transitions in self-reported musculoskeletal pain and interference with activities among newspaper workers. IWH Working Paper #175 (2001)

Cole DC, Ibrahim S, Shannon H. Predictors of repetitive strain injuries at work among Canadians. IWH Working Paper #176. (2001)

Cole DC, Hyatt D, Sinclair S. Coming to grips with economic causes, costs and efficiency.

IWH Occasional Paper #4 (1998)

Cole DC, Definition and causation of RSI/WMSD: A background paper for ABuilding common ground: Preventing and treating repetitive strain injuries@, Phase II Conference. IWH Occasional Paper #15 (1999)

Unpublished Documents

Hancock T, Saunders D, Cole DC. Our chemical society: chemicals, environment and health. Toronto: City of Toronto, Department of Public Health, Health Advocacy Unit, June 1981, 135 pp.

Byrne PN, Cole DC, Donohue A. Poverty, health and health promotion. Report to Health Promotion Directorate, Health and Welfare Canada. Toronto, Dec 1983.

Cole DC. Aportes para la insercion de contenidos de salud y seguridad en el uso de plaguicidas en el sistema educativo de Region II. Leon, Nicaragua: Ministry of Health. Aug 1986, 14 pp.

Chong J, Mummery V, Cole DC. Environmental and occupational health training modules (3) for Ontario Ministry of Health. 1987-88.

Lindsay EA, Cole DC, Heale JA, Davis DA. Environmental/occupational health education program-evaluation of the regional workshops which focussed on the problem of the disposal of hazardous waste for the Ontario Ministry of Health. McMaster University, Health Sciences. Feb 28, 1989, 22 p + appendices.

Cole DC. Using health information to evaluate health services in the Sioux Lookout Zone. In: Scott-McKay-Bain Health Panel. Achieving health for all in the Sioux Lookout zone. From Here to There: steps along the way. Companion Documents. Sioux Lookout-Toronto. Oct 1989, pp 53-68.

Chase C, Cole DC, Campbell J. Planning for health in Kichenuhmaykoosib. Mississauga. June 1990, 30 p & appendices.

Cole DC. Impacts of worker health of Ontario Hydro's 25 year demand supply plan. In: The Public Health Coalition: Ontario Public Health Association/International Institute of Concern for Public Health. Experts' Reports. Vol I. EA-90-01. Nov 1992, pp199-246.

Cole DC. Cancer in the automotive industry: a map of the literature. Report to Industrial Disease Standards Panel. July 1994, 20 p & appendices.

Heinzl R, Cole DC. Gibson B. Environmental health module for community medicine residents. McMaster Environmental Health Program resource paper. Aug 1994, 49 p.

Pengelly LD, Cole DC. Indicators of air quality in areas of concern. Report for Health Canada. Hamilton: Institute of Environment and Health. March 1995, 18 p & app.

Cole DC. Epidemiologic evidence for indicators of biological contamination and effectiveness of control methods in groundwater supplied municipal drinking water systems. Report to Medical Officer of Health, Regional Municipality of Halton. Jan 1996, 11p.

Pengelly LD, Cole DC, Eyles J, Silverman FS, Hustler R. Health based indicators of air quality in communities. Report to Health Canada. Hamilton: Institute of Environment and Health. March 1996, 48 p & appendices.

Sheeshka J, Young-Leslie H, Cole DC, Kraft D, Hooper M, Keating L, Schwartz C, Fok C. Sport fish and wildlife consumption study in areas of concern. Interim Report to Health Canada. March 1996, 80 p & appendices.

Garvin T, Underwood J, Fraser K, Cole DC, Eyles J. Sun safety in Hamilton-Wentworth. Report for Hamilton-Wentworth Regional Public Health Department. Vol.10, No. 2. Aug 1996.

The Fish & Wildlife Nutrition Project: Cole DC, Dawson J, Eyles J, Keating L, Khan H, Kraft D, Murkin E, Schwartz C, Sheeshka J, Waugh A. Great Lakes fish eaters project: dietary survey & assessment of potential risks & benefits. Technical Report - Version to Jill Kearney, Health Canada.27 Mar 1997.

Pengelly LD, Cole DC, Szakolcai A, Bell R. Human Health Working Group report to Hamilton-Wentworth Air Quality Initiative. Hamilton: Institute of Environment and Health and Ontario Ministry of Environment and Energy. May 1997.

Elliott SJ, Krueger P, Cole DC, Hall R, Voorberg N, Thorne S, Wakefield S. Perceptions of air pollution: the north Hamilton survey. Prepared for the Hamilton Air Quality Initiative and the Ontario Ministry of Environment and Energy. Hamilton: Environmental Health Program. May 1997.

Wells R, Shannon HS, Cole DC, Norman R. Electromyographic protocols for measurement of exposure in VDT and health research. Johns Hopkins University, Boston, MA. Mar 1998, 80 pages.

Frank JW, Yassi A, Stock S, Guzmán J, Clarke JA, Friesen M, Cole DC. Work-ready: Return to work approaches for people with soft tissue injuries: (i) Facilitator=s Manual; (ii) Workshop Participant=s Booklet; and (iii) Work-ready case studies. Toronto: HEAL*Net*, March 2000

The Fish & Wildlife Nutrition Project: Sheeshka J, Cole DC, Kraft D, Dawson J, Scott F, et al. Communicating fish advisory information: a monograph. Prepared for Health Canada, Great Lakes 2000 Program. Toronto: Strategic Communications, May 2000.

The Fish & Wildlife Nutrition Project: Sheeshka J, Cole DC. (ed). Great lakes fish eaters project: assessment of potential risks & benefits. Final Report to: Health Canada, July 2000.

Wells R, Norman R, Brawley L, Cole DC, Frazer M, Greco L, Kerr MS, Kerton R, Laing A, Neumann P, Theberge N. Research at work: Implementation and evaluation of a particpatory ergonomics process at The Woodbridge Group **C** Tilbury Plant. University of Waterloo: 2000.

Robson LS, Severin C, Cole DC, Hepburn G. Institute for Work & Health - St. Michael=s Hospital collaborative development of a healthy workplace balanced scorecard: Identification of SMH priorities in employee health and safety and potential indicators. Interim Report and Discussion Paper, 2001.

Cole DC, McGuire W, Lemieux-Charles L, Robson LS. Multi-level performance measures for the accreditation of Canadian health care organizations. HEALNet supported project, 2001.

Presentations at Meetings

Invited

Stock SR, Cole DC, Chong J. Tennassee M. Occupational health under the Canadian publicly funded health system. APHA Annual Scientific Conference. New York, NY. 1 Oct 1990.

Cole DC, et al. Assessing health impacts of pesticide use in the potato farming region of Carchi, Ecuador - work in progress. Paper for workshop on Measuring Health and Environmental Effects of Pesticides. Bellagio, Italy. 30 Mar - 3 Apr 1992. 36 pp.

Cole DC. Pesticide health problems and family physicians. College of Family Physicians of Ontario Annual Scientific Conference. Toronto. Nov 1992.

Cole DC. Environmental health in Canada. Society of Occupational and Environmental Health Conference on the Impact of NAFTA. Washington, D.C. Sept 1993

Cole DC, Abelsohn A. Environmental history taking. College of Family Physicians of Ontario Annual Scientific Conference. Toronto. Nov 1993.

Crissman C, Cole DC. Pesticide use and farm worker health in Ecuadorian potato production. Allied Social Science Associations Meetings. Boston, Mass. 3-5 Jan 1994.

Poon R, Kearney J, Cole DC. Cotinine and Glucaric Acid. Great Lakes Health Effects Program Science Workshop. Aylmer, Quebec. 1-3 Mar 1994.

Cole DC, Gibson BL, et al. Exposure to contaminants through fish and wildlife consumption in Great Lakes populations. Great Lakes Health Effects Program Science Workshop. Aylmer, Quebec. 1-3 Mar 1994.

Cole DC. Physicians and Environmental Health: Overcoming educational obstacles - the Canadian experience. Great Lakes Environmental Health Curriculum Workshop. 4-6 Nov 1994.

Cole DC. Biomarkers from a clinical epidemiology perspective. Health Canada Biomarkers Workshop. Ottawa, Ontario. 9-10 Jan 1995.

Cole DC. Indicators of environment and health in local state of environment/ sustainable development reporting. Ontario Air and Waste Management Association's Annual Spring Conference. Hamilton, Ontario. 1 May 1995.

Kearney J, Cole DC. Great Lakes basin anglers exposure assessment study. Sharing Knowledge, Linking Sciences: an International Conference on the St. Lawrence Ecosystem. Cornwall, Ontario and Massena, New York. 10-12 May 1995.

Cole DC. Upper extremity soft tissue injuries. Annual Conference of the Occupational and Environmental Medical Association of Canada. Toronto. 30 Sept- 4 Oct 1995.

Cole DC. Reproductive outcomes and environmental risks. Symposium on Environmental Risk - Unpacking the Black Box. Hamilton. 6-8 Nov 1995.

Cole DC & the Fish and Wildlife Nutrition Project Team. A shore survey of fish and wildlife consumption among multi-ethnic fishers. First Buffalo Environmental Health Sciences Conference. Amherst, New York. 19 Apr 1996.

Cole DC, Frank JW, Sinclair SJ, Johnson SH, Shannon HS, Bombardier C, Beaton DE. Prevention of back pain disability at work in persons who already have symptoms. Keynote address: Human Factors Association of Canada 28th Annual Conference. Kitchener, ON. 23-26 Oct 1996.

Cole DC. Pesticide exposure and potential health effects - certain and uncertain science and its implications for children's health. Children's Health and Environment Workshop. Toronto, ON. 28 Oct 1996.

Cole DC, Beaton DE. Upper extremity guidelines, prognosis and treatment of upper extremity musculoskeletal disorders. American College of Occupational and Environmental Medicine's State-of-the-Art Conference on Managed Care and Occupational Medicine. Toronto, ON. 27-31 Oct 1996.

Cole DC, Hyatt D, Sinclair SJ. Economics of RSI/WMSD: Causes, costs and efficiency. Ontario Physiotherapy Association's First International Conference on RSI. Toronto, ON. 15-16 Jan 1997.

Cole DC. Secondary prevention of back pain disability at work. 10th Inter-Urban Pain Conference. Chronic Pain: Disability and Management. London, ON. 21 Nov 1997.

Chung J, Cole DC. Reporting and non-reporting repetitive strain injury to the workplace: a case study using qualitative and quantitative methods in a large newspaper. Health & Society Group, McMaster University. Toronto, ON. 8 Jan 1998.

Cole DC. Workplace changes and RSI/WMSD: A case example. USWA National Health, Safety and Environment Conference. Toronto, ON. 19-20 Jun 1998.

Beaton DE, Cole DC, Manno M, Hogg-Johnson S, Bombardier C and the Worksite Upper Extremity Group. The implication of case definition in surveys of work-related musculoskeletal disorders. Presentation to PREMUS/ISEOH=98. Helsinki, Finland. 20 Sept 1998.

Valaitis R, Chambers L, Cole DC, Ehrlich A, O=Mara L, Rideout L, VanBerkel C. AStop, look & listen: a multi-media tool for community action@. 5th Canadian Congress on International Health, Partnerships for Health: A Work in Progress, Ottawa/Hull, ON. 15 Nov 1998.

Cole DC. Eco-Salud Project. Production - Environmental - Health Tradeoffs Project Meeting, Quito, Ecuador. 8-10 Mar 1999.

Cole DC. Pesticides and health in potato production in Highland Ecuador, El Centro Internacional de Papas and Instituto National Autonomo de Investigaciones, Ambuqui, Ecuador. Oct 1999.

Berti P, Cole DC, Crissman C. Pesticides and health in potato production in Highland Ecuador. Canadian Society for International Health. Ottawa, ON. Nov 1999.

Cole DC, Kramer D. Looking at both biomechanical and psychosocial effects. Industrial Accident Prevention Association Conference. Toronto ON. 10-12 Apr 2000.

Cole DC, Brooker A-S, Clarke J, Early Claimant Cohort Prognostic Modeling Working Group & HEALNet WorkReady Research Team. Organizational factors & return to work (RTW) following lost-time injury (LTI). National Occupational Injury Research Symposium (NOIRS) 2000. National Institute for Occupational Safety and Health (NIOSH). Pittsburg, PA. 17-19 Oct 2000.

Cole DC. Research and balancing values with economics. Health, Work and Wellness Institute of Canada Conference 2000. Toronto, ON. 23-25 Oct 2000.

Morris B, Cole DC. Indicators of human health for freshwater ecosystems. Paper for Consensus Conference on Environmental Health surveillance organized by the Health Professionals Taskforce on the International Joint Commission. Quebec City, Oct 2000.

Ferrier S, Cole DC, Deverell J. Work-related Stressors and Musculoskeletal Problems at The Toronto Star. Roundtable, American Public Health Association meeting. Boston, MA.12-16 Nov 2000.

Cole DC, London L. Pesticides, women and international development: an ecosystem approach to human health. Public Lectures (in Montreal, Halifax and Edmonton) on the Ecohealth Tour 2001 Programme. 6-13 Feb 2001.

Wells R, Cole DC and the Worksite Upper Extremity Research Group. Intervention in computer intense work. In: Sandsjö L, Kadefors R editors. Prevention of muscle disorders in computer users: scientific basis and recommnedations. Proceedings of the 2nd PROCID Symposium. 8-10 March, 2001. West Göteborg, Sweden: National Institute for Working Life.

Antle J. Cole DC. Pesticide usage in developing countries. ABCDE Workshop--Environmental

Health Issues in Developing Countries. Presentation at the World Bank. Washington, DC. 1 May 2001.

Cole DC. Reduce injuries and create a healthy workplace, by paying attention to both the physical and psychosocial workplace factors. Information Exchange meeting with the Institute for Work & Health and Safety Associations. 24 May 2001.

Robson L, Lemieux-Charles L, McGuire W, Cole DC. Quality of worklife performance indicators. 2001 National Healthcare Leadership Conference and Exhibition, Winnipeg, Manitoba, 4-6 June, 2001.

Cole DC. Changing Agro-Ecosystem Managment to Reduce Pesticide Use and Improve Human Health. CIDAInternational Cooperation Days. Ottawa Congress Centre, Ottawa, 18-20 June 2001.

Contributed

Peer-reviewed

Cole DC. Health education and community oriented primary care. College of Family Physicians of Canada, Toronto, ON. Apr 1983.

Cole DC, Weinger M. Health promotion and pesticides: the Nicaraguan strategy. APHA Annual Scientific Conference, New Orleans, Louisiana, USA. Oct 1987.

Cole DC, Chong J, Mummery V, Lindsay L, Heale J, Davis D. Environmental and occupational health education program. CPHA Annual Scientific Conference. Winnipeg. MN. Jun 1989.

Cole DC, Lindsay EA, Willms DG. From fast to aboriginal health authority in the Sioux Lookout Zone: the role of McMaster's consultation to the Scott-McKay-Bain Health Panel. CPHA Annual Scientific Conference. Toronto, ON. 27 Jun 1990.

Cole DC, Hurst D. Health impacts of Ontario Hydro's 25 year demand supply plan. CPHA Annual Scientific Conference. Yellowknife. Jul 1992.

Cole DC, Stock SR, Gibson ES (1992): Workplace based interventions to reduce overuse disorders of the neck and upper extremity: an epidemiologic review. 25th Anniversary of the Human Factors Association of Canada. Hamilton ON. pp 263-269.

Cole DC, Carpio F, Leon N, Bravo V, Almeida HD. Pesticide poisonings in Highland Ecuador. APHA 121st Annual Meeting. San Francisco, CA. Oct 93.

Cole DC, Delisle H. Community assessment of environmental health concerns. Ecosystem Health and Medicine. Ottawa, ON. Jun 1994.

Kearney J, Cole DC. Great Lakes anglers exposure assessment study. Canadian Society for Epidemiology and Biostatistics. St. John's, Newfoundland. 16-19 Aug 1995.

Shannon HS, Cole DC, Beaton DE. Work-related musculoskeletal disorders, stress and chronicity. Work, Stress and Health ›95: Creating Healthier Workplaces. Washington, DC. 13 Sept 1995.

Shannon HS, Cole DC, Beaton DE. Work-related musculoskeletal disorders, case management and chronicity. 2nd International Scientific Conference on Prevention of Work-related Musculoskeletal Disorders, PREMUS ›95. Montréal, Québec. 25-28 Sept 1995.

Sinclair SJ, Erdeljan S, Hogg-Johnson S, Kralj B, Mondloch M, Cole DC, Frank JW. Evaluation of effectiveness of an early, active intervention program for workers with musculoskeletal injuries. 2nd International Scientific Conference on Prevention of Work-related Musculoskeletal Disorders, PREMUS ›95. Montréal, Québec. 25-28 September 1995.

Hudak PL, Amadio PC, Bombardier C and the Upper Extremity Collaborative Group (*includes*:

Cole DC). Development of an upper extremity health status instrument. 2nd International Scientific Conference on Prevention of Work-related Musculoskeletal Disorders. PREMUS 95. Montréal, Québec. 25-28 Sept 1995.

Frank JW, Brooker A-S, Kerr MS, Shannon HS, Cole DC. Limitations on the use of attributable risk estimates for deciding workplace attribution of occupational health outcomes. 2nd International Scientific Conference on Prevention of Work-related Musculoskeletal Disorders, PREMUS ›95. Montréal, Québec. 25-28 Sept 1995.

Cole DC. A framework for understanding health risks and benefits of fish and wildlife consumption. IAGLR's 39th Conference on Great Lakes Research. Erindale College, Mississauga, ON. 26-30 May 1996.

Kearney J, Cole DC. Great Lakes anglers' exposure assessment study. IAGLR's 39th Conference on Great Lakes Research. Erindale College, Mississauga, ON. 26-30 May 1996.

Sheeshka JD, Cole DC, Hooper M, Kraft D, Young-Leslie H. Quantitative results of a shoreline assessment of fish and wildlife consumption. IAGLR's 39th Conference on Great Lakes Research. Erindale College, Mississauga, ON. 26-30 May 1996.

Jerret M, Eyles J, Cole DC. Accounting for environmental equity: an audit of the income distribution of pollution across the 49 counties of Ontario. 20th Annual Meetings of the Canadian Regional Science Association. Brock University, St. Catharines, ON. 31 May - 1 June 1996.

Gibson BL, Cole DC, Eyles J. The environmental burden of human illness in the Great Lakes: setting priorities. 8th Annual Conference of the International Society for Environmental Epidemiology. Edmonton, Alberta. 17-21 Aug 1996.

Kearney J, Cole DC. Levels of environmental contaminants in blood and hair samples from Ontario anglers. 8th Annual Conference of the International Society for Environmental Epidemiology. Edmonton, Alberta. 17-21 Aug 1996.

Cole DC, Julian J, Carpio F, Leon N. Agricultural pesticide exposure and preipheral neurologic outcomes: a cross-sectional survey. 8th Annual Conference of the International Society for Environmental Epidemiology. Edmonton, Alberta. 17-21 Aug 1996.

Shannon HS, Cole DC, Polanyi MF, Beaton DE, Chung J, Ferrier SE, Mondloch MV, Smith JM. Studying WMDS's in newspaper office workers: collaborating with labour and management. International Committee on Occupational Health. Sept 1996.

Frank JW, Sinclair SJ, Hogg-Johnson S, Shannon HS, Bombardier C, Beaton DE, Cole DC. How early is too early? The instructive case of occupational back pain rehabilitation. 18th World Congress of Rehabilitation International. Auckland, New Zealand. 15-20 Sept 1996.

The Upper Extremity Collaborative Group (includes Cole DC). Development of an upper extremity outcome measure: the "DASH" (Disabilities of the Arm, Shoulder and Hand). International Quality of Life Meeting. Paris, France. Oct 1996.

Cole DC, Dawson J, Sheeshka J, Keating LJ, Owens S, Kraft D. Quantitative results of an assessment of fish and wildlife consumption in Ontario Areas of Concern - 1995-6 data. Great Lakes/St. Lawrence Health Conference 97. Montreal, Qué.12-15 May 1997.

Dawson J, Cole DC, Young-Leslie H, Sheeshka J, Waugh A, Kraft D, Kearney J, Owens S. Some fish to fry: perceptions of the risks and benefits of Great Lakes fish consumption. Great Lakes/St. Lawrence Health Conference 97. Montreal, Qué.12-15 May 1997.

Sheeshka J, Kraft D, Dawson J, Cole DC. The urban fishery: recreation, culture & food.

International Conference on Sustainable Urban Food Systems. Toronto, ON. May 1997.

Hogg-Johnson S, Cole DC, Frank JW et al. Early prognostic factors for duration of benefits among workers with compensated soft tissue injuries. Abstract at the 2nd International forum for primary care research on low back pain. The Hague, The Netherlands. 30-31 May 1997.

Wells R, Woo H, Norman R, Cole D, Shannon H, Bao S. EMG of the forearm and hand as an exposure method for epidemiologic studies of WMSD in office environments. International Ergonomics Association. Aug 1997.

Valaitis R, Chambers L, Cole D, Ehrlich A, O=Mara L, Rideout L and Van Berkel C. Stop, look and listen: wsing interactive multimedia technology to teach the process of community action. Involvement of communities in health professions education: Challenges, opportunities and pitfalls. 20th Network Anniversary Conference. Mexico City, Mexico. 19-24 Oct 1997.

Cole DC, Antle J, Crissman C, Julian J, Carpio F. Health Effects of pesticide use and tradeoffs between health and agriculture production in Ecuador. P 158 of Book of Abstracts from International conference on pesticide use in developing countries: Impact on health and environment. San José, Costa Rica. 23-28 Feb 1998.

Cole DC, Carpio F, Merino R, Leon N, Crissman C. Characterizing exposure to pesticides in potato production in Ecuador. P 160 of Book of Abstracts from International conference on pesticide use in developing countries: Impact on health and environment. San José, Costa Rica. 23-28 Feb 1998.

Keir PJ, Wells RP, Cole DC, Manno M, Beaton DE, Grossman J. Surface EMG as a diagnostic aid for upper-limb work-related musculoskeletal disorders. North American Congress of Biomechanics (NACOB). Waterloo, ON. Aug 1998.

Ibraham SA, Goel V, Shannon HS, Cole DC. Job strain, general health perceptions and health care utilization among Canadian workers. 1st International ICOH Conference on Psychosocial Factors at Work. Copenhagen, Denmark. 24-26 Aug1998.

Beaton DE, Cole DC, Manno M, Hogg-Johnson SA, Bombardier C, and the Worksite Upper Extremity Group. The implication of case definition in surveys of WMSD. PREMUS/ISEOH Conference. Helsinki, Finland. 21-25 Sept 1998.

Wells R, Norman R, Shannon HS, Cole DC, Woo H, Bao S. Exposure assessment in the upper limbs of VDT operators using electromyography: responsiveness to different tasks. PREMUS/ISEOH Conference. Helsinki, Finland. 21-25 Sept 1998.

Cole DC, Beaton DE, Swift M, Manno M, and the Worksite Upper Extremity Group. Change in musculoskeletal problems of the neck and upper limb among newspaper workers: a one-year follow-up study. PREMUS/ISEOH Conference. Helsinki, Finland. 21-25 Sept 1998.

Smith JM, Cole DC, Manno M, Beaton DE. Comparing severity indices for upper extremity work-related musculoskeletal disorders (WMSDs) across multiple indicators. PREMUS/ISEOH Conference. Helsinki, Finland. 21-25 Sept 1998.

Beech-Hawley L, Wells R, Cole DC and the Worksite Upper Extremity Group. The experience sampling method: an approach to the study of deadlines in newspaper workers. Human Factors Association of Canada Annual Conference. Mississauga, ON. Oct 1998.

Arbuckle TE, Burnett R, Cole DC, Teschke K, Dosemeci M, Bancej C, Zhang J. Predictors of herbicide exposure in farm applicators and misclassification. 2000 Annual Meeting of the International Society of Exposure Analysis. Monterey, California. 24-27 Oct 2000.

Wainman BC, Cole DC, Harper PA, Corda C, Ryan JJ, Weber JP. Society of Toxicology, Maternal Environmental Contaminant Levels and Time to Pregnancy in Primiparae. 25-29 March 2001.

Theberge N, Granzow K, Neumann P, Brawley L, Frazer M, Laing A, Norman R, Wells R, Kerton R, Greco L, Cole DC. 32nd Annual Congress: Association of Canadian Ergonomists. Participatory Ergonomics: Assessing the Impact of Different Forms of Involvement on Reported Outcomes. Montreal, Que. Sept 2001.

Hogg-Johnson S, Cole DC, Lee H and the Worksite Upper Extremity Group. Tracking impacts on disability outcomes of workplace research/interventions using administrative data sources. Accepted: 4th International Scientific Conference on Prevention of Work-related Musculoskeletal Disorders (PREMUS). Amsterdam, The Netherlands. 30 Sept - 4 Oct 2001.

Crissman CC, Cole DC, Sherwood SS, Espinosa P. Potato production and pesticide use in Ecuador: Linking impact assessment research and rural development intervention for greater eco-system health. Impact Assessment Workshop.

Strong S, Reardon R, Shannon HS, Baptiste S, Cole DC, Clarke J, Costa M, McKenzie D, Sinclair S, Gibson E. Practice patterns of functional capacity evaluations in employercompensation systems. Abstract at the Canadian Association for Research on Work and Health (CARWH). Toronto, ON. 18 Nov 2001.

Lewchuk W, Robertson D, Cole DC, Kerr MS, Haines T, Wigmore D. CAW/McMaster blood pressure project. Abstract at the Canadian Association for Research on Work and Health (CARWH). Toronto, ON. 18 Nov 2001.

Hogg-Johnson S, Cole DC, Lee H, Subrata P. Using administrative data sources to track WMSD-related outcomes. Abstract at the Canadian Association for Research on Work and Health (CARWH). Toronto, ON. 18 Nov 2001.

Crissman CC, Cole DC, Sherwood S, Espinosa P, Yanggen D. Potato production and pesticide use in Ecuador: linking impact assessment research and rural development intervention for greater eco-system health. International Conference on Agricultural Research and Development. San José, Costa Rica. 4-7 Feb 2002.

Posters

Peer-Reviewed:

Cole DC, Sinclair SJ, Frank JW et al. Evaluating community based clinics for treatment of soft tissue injuries in Ontario workers. CPHA Annual Scientific Conference. St. Johns, Newfoundland. July 1993.

Cole DC, Sinclair SJ, Frank JW, Hogg-Johnson et al. Evaluating a community based rehabilitation system for treatment of occupational soft tissue injuries. APHA 121st Annual Meeting. San Francisco, CA. Oct 93.

Cole DC, Julian JA, Carpio F, Leon N. Pesticide health impacts on Ecuadorian potato farms. Canadian Society for Epidemiology and Biostatistics. St. John's, Newfoundland. 16-19 Aug 1995.

Cole DC, Kearney J, Gilman AP, Ryan JJ. Plasma PCB, Dioxin and Furan levels in Ontario Great Lakes anglers. Dioxin '95. Edmonton, Alberta. 21-25 Aug 1995. (Obtained first prize out of 300 poster applicants)

Blakey DH, Bayley JM, Huang KC, Kearney J, Cole DC. Frequency of structural chromosomal aberrations measured using conventional Giemsa staining and three-colour chromosome painting in a population of Great Lakes fish eaters. Environmental Mutagens in Human Populations. Prague, Czech Republic. 19-25 Aug 1995.

Cole DC, Julian J, Carpio F, Leon N. Agricultural pesticide exposure and peripheral neurologic outcomes: a cross-sectional survey. 8th Annual Conference of the International Society for Environmental Epidemiology. Aug 17-21, 1996. Edmonton, Alberta.

The Upper Extremity Collaborative Group (includes Cole DC). Development of an upper extremity outcome measure: the "DASH" (Disabilities of the Arm, Shoulder and Hand). American College of Rheumatology 60th National Scientific Meeting. Orlando, Florida. 18-22 Oct 1996.

Kearney J, Cole DC, Dawson J, Khan H, Sheeshka J, Waugh A, Weber JP. Overview of the Great Lakes fish eaters' study. Great Lakes/St. Lawrence Health Conference 97. Montreal, Qué. 12-15 May 1997.

Wang H, Hogg-Johnson S, Cole DC, Corey P. A six year follow up record linkage study of recurrences of compensable soft-tissue injuries. Canadian Society of Epidemiology and Biostatistics. London, ON. 25-28 May 1997.

Cole DC, Ibrahim SA, Shannon HS, Scott F, Eyles J, Goel V (1998a). Job demand/control, work factors and depressive episodes among Canadian workers: a gender analysis of the 1994 National Population Health Survey (NPHS).1st International ICOH Conference on Psychosocial Factors at Work. Copenhagen, Denmark. 24-26 Aug 1998.

Ibraham SA, Cole DC, Shannon HS, Scott F, Eyles J, Goel V. Job strain, activity restriction and musculoskeletal disorders among Canadian workers: an analysis, by gender of the 1994 National -Population Health Survey. PREMUS-ISEOH =98. Helsinki, Finland. 21-25 Sept 1998.

Cole DC, Ibrahim SA, Shannon HS, Scott F, Eyles J, Goel V. Job strain, job satisfaction and emotional distress among Canadian workers: a general analysis of the 1994 National Population Health Survey. PREMUS-ISEOH =98. Helsinki, Finland. 21-25 Sept 1998.

Cole DC, Ibrahim SA, Shannon HS, Scott F, Goel V. Determinants of psychological well-being in the Canadian working population: a structural equation modelling approach. Work, Stress and Health ›99: Organization of Work in a Global Economy. American Psychological Association/NIOSH. Baltimore, Maryland. 11-13 Mar 1999.

Cole DC, Kerr MS, Brawley LR, Ferrier S, Frazer MB, Hogg-Johnson S, Kerton R, Neumann WP, Norman RW, Polanyi MF, Shannon HS, Smith JM, Wells RP. Workplace interventions for health: Dilemmas & challenges. ASAC-IFSAM 2000 (Administrative Sciences Association of Canada), (International Federation of Scholarly Associations of Management). Montreal, Que. 9-11 July 2000.

LaBella D, Strong S, Reardon R, Shannon HS, Baptiste S, Cole DC, Clarke J, Gibson E, Sinclair S. Analysis of organizational and stressor profiles: Preliminary findings from a functional assessment study. McMaster University Student Research poster. July 2000.

Cole DC, Polanyi M, Wells RP. Workplace Interventions: program implementation or policy change? 4th International Scientific Conference on Prevention of Work-related Musculoskeletal Disorders: PREMUS =01. Amsterdam, The Netherlands. 30 Sept - 4 Oct 2001.

Frazer MB, Wells RP, Norman RW, Theberge N, Cole DC, Kerr MS, Laing AC, Brawley LR, Kerton R. Assessment of the effectiveness of evidence-based ergonomic decisions in workplaces for prevention of work-related musculoskeletal disorders (WMSD). 1st National Symposium: Canadian Association for Research on Work and Health (CARWH). Toronto. 18 Nov 2001.

Cole DC, Beaton DE, Ferrier SE, Hepburn G, Hogg-Johnson S, Kerr MS, Kramer D, Polanyi MF, Robson LS, Shannon HS, Swift M, Wells RP, Frazer M, Norman R, Theberge N, Moore A. Workplace interventions to reduce the burden of work-related morbidity: A program of research on evaluating implementation and effectiveness. 1st National Symposium: Canadian Association for Research on Work and Health (CARWH). Toronto. 18 Nov 2001.

Mustard CA, Cole DC, Shannon HS, Pole J, Sullivan TJ, Allingham R, Sinclair S. Does the decline in workers= compensation claims 1990-2000 in Ontario correspond to a decline in the incidence of workplace injuries? 1st National Symposium: Canadian Association for Research on Work and Health (CARWH). Toronto. 18 Nov 2001.

Laing AC, Frazer MB, Wells RP, Norman RW, Theberge N, Cole DC, Kerr MS, Brawley LR. Evidence Based Ergonomics Decisions B Effects of Knowledge Transfer on Corporate Redesign Strategies. HEALNet Researchers Invitational Workshop. Ottawa. 23 Nov 2001.

Administrative Responsibilities - McMaster

1989-90 **DME Student Representative.** Regional Service Program Committee

1989-91 **Resident Member.** Occupational Medicine Residency Program Committee

1990-91 **Senior Resident.** Community Medicine Residency Program

1991-2001 **Member.** Community Medicine Residency Program Committee

1993-94 **Institute for Environment and Health Representative and Co-Chair**.

Task Force on Environmental Health for Health Professionals

1995-96 **Director.** Community Medicine Residency Program

Relevant Community Service

Presentations

Health effects of indoor air. Bipartite Federal Building Safety Committee. Jan 1992.

Health impacts of environmental contaminants in the Great Lakes. Credit Valley Hospital Family Practice Rounds. Sept 1992.

Health concerns and drinking water quality. Public Liaison Committee for the Georgetown Water Supply. 8 Jun 1994.

Pre-pregnancy environmental health concerns. St. Lawrence Forum on Making Healthier Babies: What You Can Do Before You Get Pregnant. 12 Apr 1995.

Human health in ecosystems - lead presentation of session and facilitator for breakout group on sport fish and wildlife consumption study. BARC's (Bay Area Restoration Council) 4th Annual Fall Workshop: Healthy Harbour-Healthy People. 25 Nov 1995.

Women's health and environment. Hamilton-Burlington Junior League. Feb 1996.

Health based indicators of air quality. Co-facilitator: London Environmental Network Grosvenor Lodge. 22 Feb 1996.

Health based indicators of air quality. Co-facilitator: Norfolk Round Table on Environment and Economy. 7 Mar 1996.

Cole DC, Voorberg N. Air pollution and smoking survey of elementary school students. Region of Hamilton-Wentworth Health and Social Services Committee. 11 May 1996.

Fish and wildlife consumption and reproduction. Facilitator: Reproductive Health and the Environment Symposium. Toronto, ON. 13 May 1996.

Measuring pesticide health impacts in rural Ecuador. Clinical Epidemiology and Biostatistics Rounds. McMaster Health Sciences Centre, Hamilton, ON. 13 Jun 1996.

Pesticide exposure and potential health effects: certain and uncertain science and its implications for children's health. 28 Oct 1996.

Environmental influences on pre-conceptional health. Facilitator: Haldimand-Norfolk Regional Health Department Conference on Pre-conceptional Health: more than a healthy lifestyle. Mississauga, ON. 8-9 May 1997.

Hogg-Johnson S, Cole DC. Managing in the grey zone: the natural history of recovery and its effect on treatment approaches for soft tissue injuries. Grand Rounds presentation to Workplace Safety & Insurance Board Toronto, ON. 5 Jan 1999.

Cole DC, Schofield M. The causes, assessment, diagnosis and management of upper extremity disabilities. Grand Rounds presentation to Workplace Safety & Insurance Board. Toronto, ON. 9 Feb 1999.

Cole DC. Definition & causation of RSI/WMSD=s. RSI Action Planning Forum. Toronto, ON. 16-17 Feb 1999.

Cole DC. Work-related disease and illness. Communication, Energy and Paper Workers Union Conference. 3 Oct 1999.

Cole DC. Research on workplace reproductive hazards for women and men. At: AReclaiming our Birthright@ Reproductive Health Conference. Toronto, ON. 3-6 Oct 1999.

Cole DC, Ibrahim S, Shannon HS. Work, stress and mental health. Presentation to Department of Public Health Sciences, University of Toronto. 14 Oct 1999.

Cole DC. Keyboarding and epicondylitis. Presentation to the WSIB CME/Journal Club. Toronto, ON. 23 Nov 1999.

Cole DC, Mustard CA. Prevention in the workplace over the past decade: has it made a difference? IWH Research Advisory Council. Toronto, ON. 25-26 Apr 2000.

Cole DC, Kerr MS, Brawley LR, Ferrier S, Frazer MB, Hogg-Johnson S, Kerton R, Neumann WP, Norman RW, Polanyi MF, Shannon HS, Smith JM, Wells RP. Workplace interventions for health: dilemmas & challenges. Centre for Health Promotion Seminar Series, University of Toronto. Jun 2000.

Cole DC. Pesticides. Navigating Change: environmental and health peer presenter program Phase I. The Ontario College of Family Physicians, Toronto, ON. 9-11 June 2000.

Cole DC, Wainman B. Environmental contaminants and time to pregnancy - The St. Joseph's Hospital Experience, McMaster University, McMaster Institute of Environment and Health, Sept 28, 2000

Interviews for Media

Print:

Globe & Mail and Toronto Star on Community Health Centres three times over 1980's

Globe & Mail re: "Repetitive Strain Injuries" 1992.

Hamilton Spectator re: 7th Biennial International Joint Commission report 1994, AContaminants and Reproduction@ 1995 x 2 and multiple additional ones on this theme.

Radio & TV:

Canada AM re: "Repetitive Strain Injuries" 1992.

McLean Hunter Cable 10 re: "Health and Safety in the Home Workplace" 1993.

TV Ontario re: Health Effects of Environmental Contaminants "Great Lakes Alive" 1994.

CBC Radio re: "Fish and Wildlife Nutrition Project" 1996.

Sarnia Radio re: "Sport Fish and Wildlife Consumption Survey" 1997.

Women=s TV Network (WTN) and City TV, Toronto, re: Repetitive Strain Injury (RSI) 1998.

Multiple on ›RSI= for the Institute for Work & Health through media releases

International Congress on Work & Health for CBC Radio affiliates, June 1999.

Recovery Expectations Interviews with multiple media representatives, July 2001.

Board Memberships

1977-79	Injured Workers' Consultants
1982-83	Parkdale Community Health Centre
1993-94	Ferncliffe Daycare
1997-98	Occupational Health Clinics for Ontario Workers